NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

SURVIVAL ANALYSIS AND ACCESSION OPTIMIZATION OF PRIOR ENLISTED UNITED STATES MARINE CORPS OFFICERS

by

Phillip Hoglin

March 2004

Thesis Advisor:	Kathryn M. Kocher
Thesis Co-advisor:	Samuel E. Buttrey

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** March 2004	**3. REPORT TYPE AND DATES COVERED** Master's Thesis

4. TITLE AND SUBTITLE: Survival Analysis and Accession Optimization of Prior Enlisted United States Marine Corps Officers.	**5. FUNDING NUMBERS**
6. AUTHOR(S)	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A	**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited	**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

The purpose of this thesis is to firstly analyze the determinants on the survival of United States Marine Corps Officers, and secondly, to develop the methodology to optimize the accessions of prior and non-prior enlisted officers. Using data from the Marine Corps Officer Accession Career file (MCCOAC), the Cox Proportional Hazards Model is used to estimate the effects of officer characteristics on their survival as a commissioned officer in the USMC. A Markov model for career transition is combined with fiscal data to determine the optimum number of prior and non-prior enlisted officers under the constraints of force structure and budget.

The findings indicate that prior enlisted officers have a better survival rate than their non-prior enlisted counterparts. Additionally, officers who are married, commissioned through MECEP, graduate in the top third of their TBS class, and are assigned to a combat support MOS have a better survival rate than officers who are unmarried, commissioned through USNA, graduate in the middle third of their TBS class, and are assigned to either combat or combat service support MOS. The findings also indicate that the optimum number of prior enlisted officer accessions may be considerably lower than recent trends and may differ across MOS. Based on the findings; it is recommended that prior enlisted officer accession figures be reviewed.

14. SUBJECT TERMS Attrition, Accession, Commissioning sources, Cox Regression Enlistment, Manpower, Markov, Officer retention, Optimization, Parametric, Personnel Attrition, Prior-enlisted officers, Quality of Life (QOL), Recruiting, Retention, Requirements Determination, Semi-parametric, Survival Analysis, Transitional Models, Proportional Hazards.	**15. NUMBER OF PAGES** 119
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89) Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

SURVIVAL ANALYSIS AND ACCESSION OPTIMIZATION OF PRIOR ENLISTED UNITED STATES MARINE CORPS OFFICERS

Phillip J. Hoglin
Major, Australian Army
B.S., University of New South Wales, 1993

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

NAVAL POSTGRADUATE SCHOOL
March 2004

Author: Phillip J. Hoglin

Approved by: Kathryn M. Kocher
Thesis Advisor

Samuel E. Buttrey
Thesis Co-advisor

Douglas A. Brook
Dean, Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

The purpose of this thesis is to firstly analyze the determinants on the survival of United States Marine Corps Officers, and secondly, to develop the methodology to optimize the accessions of prior and non-prior enlisted officers. Using data from the Marine Corps Officer Accession Career file (MCCOAC), the Cox Proportional Hazards Model is used to estimate the effects of officer characteristics on their survival as a commissioned officer in the USMC. A Markov model for career transition is combined with fiscal data to determine the optimum number of prior and non-prior enlisted officers under the constraints of force structure and budget.

The findings indicate that prior enlisted officers have a better survival rate than their non-prior enlisted counterparts. Additionally, officers who are married, commissioned through MECEP, graduate in the top third of their TBS class, and are assigned to a combat support MOS have a better survival rate than officers who are unmarried, commissioned through USNA, graduate in the middle third of their TBS class, and are assigned to either combat or combat service support MOS. The findings also indicate that the optimum number of prior enlisted officer accessions may be considerably lower than recent trends and may differ across MOS. Based on the findings, it is recommended that prior enlisted officer accession figures be reviewed.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

There is no doubt in my mind that this thesis would have been less than half the standard of the final product if it were not for the support of my family. I would like to specifically thank Kristy, my wife, who supported and encouraged me during those inevitable apathetic stages of thesis writing, and for her understanding during late nights and prolonged absences from home. I would also like to thank my children, Jordan and Camden, who were both born during study for this thesis, and who made me realize that this thesis was never going to be my first priority so long as there was another nappy to change.

Of course this thesis could not have reached its final quality if it were not for the guidance, wisdom, expertise and dedication of Professors Kathryn Kocher and Sam Buttrey. The efficiency, accuracy and quality of feedback from both professors made the writing experience much more pleasurable than it otherwise would have been.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. BACKGROUND

Every year since 1980, in excess of 1,000 Marines Corps Officers (and occasionally over 1,600) have graduated from The Basic School which almost all United Stated Marine Corps officers attend before they receive their commission. Many of these graduates have been prior enlisted personnel who, after passing the prescribed selection criteria, have decided to continue their careers as officers in the Marine Corps.

A comparison of prior enlisted and non-prior enlisted officers may aid in determining the most effective method for obtaining and retaining officers. It is intuitive that the longer a high-performing officer remains in the Marine Corps, the greater the benefit to the service, as it requires money, experience and other resources to recruit and train replacements. It therefore follows that if one group were to exhibit greater attributes of retention and promotion, on average, than the other, then consideration should be given to increasing the accession of officers from this group.

Any decision to favor one group over another based only on retention and performance would, however, not give due consideration to the cost of each group of officers. A conflict exists where the group which has the highest levels of retention is also the most expensive to recruit and train. In reality there is both a budget for officer accessions, and a prescribed number of officers required at each rank to maintain the force structure.

1. Commissioning Sources and Cost Benefits

Although the topic of the retention of prior and non-prior enlisted Marine Corps officers has been explored previously, much of the prior research has examined only the effects of the commissioning source on the likelihood that an officer will be retained until a particular career milestone. However, although some commissioning sources are exclusive to prior enlisted officers, generalizations about the behavior of prior enlisted officers cannot be made based on the commissioning source alone because several commissioning sources accept both prior and non-prior enlisted officers.

The two commissioning sources exclusive to prior enlisted officers are Marine Enlisted Commissioning Education Program (MECEP) and Enlisted Commissioning Program (ECP). Additionally, enlisted personnel may be commissioned through a third source, the Meritorious Commissioning Program (MCP). The remaining commissioning sources, including the United States Naval Academy (USNA), Naval Reserve Officer Training Corps (NROTC), Platoon Leaders Course (PLC) and Officer Candidate Course (OCC), graduate both prior and non-prior enlisted officer candidates, albeit in varying proportions.

The media and Congress occasionally focus on the cost of maintaining so many commissioning sources. Skeptics of the cost of officer commissioning sources for the Navy point to the average cost per officer accession from USNA exceeding $229,000 as evidence that there must be a better alternative.[1] Other evidence suggests that USNA graduates have lower attrition and comparable marginal costs resulting in the USNA actually being more cost-effective for Navy officer accessions than other commissioning sources.[2]

The cost-effectiveness debate for the USMC is further complicated in comparison to the Navy by its large number of commissioning sources and the relatively high proportion of officers who come through the ranks (prior enlisted), compared with other services. Deciding on the most cost effective distribution of officers across the seven commissioning sources therefore poses a multidimensional problem.

Neither prior enlisted or non-prior enlisted officers can alone provide enough officers to sustain the Marine Corps. However, it is possible that one group may be more successful in its commissioned careers and more 'beneficial' to the USMC in terms of performance and retention than the other group. An analysis to determine which group of officers, the prior enlisted or non-prior enlisted, currently remain in the USMC for longer terms could provide some insight as to which group should be targeted for

[1] Bernard and Mehay, *An Analysis of Alternate Commissioning Programs for Navy Officers* (Monterey: Naval Postgraduate School, 2003), 4.

[2] Ibid., table 1. Also see Bowman, W.R. *Cost-Effectiveness of Service Academies:New Evidence from Navy Warfare Communities*, (Annapolis: United States Naval Academy, 1995), table 17.

commissioning. Maximizing The Basic School (TBS) intake of the higher retention group could have long-term benefits for the USMC. This benefit, however, would need to be balanced by the cost of each commissioning program.

B. OBJECTIVES AND RESEARCH QUESTIONS

The purpose of this thesis is twofold. The first research area concerns identifying the effect that being prior enlisted has on officer longevity. The second research area attempts to identify an optimal mix of prior and non-prior enlisted officers in the USMC with respect to a given set of constraints, which may be varied according to pre-specified conditions thereby providing a sensitivity analysis.

Specifically, the research focuses on answering the following questions:

- What effect does being a prior enlisted Marine have on officer longevity, *ceteris paribus*?
- What is the optimal mix of prior and non-prior enlisted officer accessions such that the force structure can be maintained without resulting in vacancies at various ranks and without exceeding the fiscal budget?

C. SCOPE AND LIMITATIONS

This thesis examines the careers of prior enlisted United States Marine Corps (USMC) officers with respect to their completed years of commissioned service (YCS) by analyzing officer cohorts from 1986 to 1999 inclusive. Prior-enlisted officers are defined as those officers who have held any enlisted rank from E-1 to E-9 prior to commissioning through TBS.

The necessary number of prior enlisted and non-prior enlisted accessions required to maintain the officer force structure will also be examined. The force structure is defined numerically as the number of officers required in each rank as determined by Headquarters Marine Corps. The performance of officers will not be considered in this thesis.

D. ORGANIZATION OF STUDY

This study is organized into eight chapters. Chapter II develops basic background information on the seven commissioning sources. The literature review, Chapter III, identifies other sources of information regarding the commissioning sources, officer accession, officer retention, and promotion. It also discusses some of the findings and methodology of related studies.

The remainder of the study is broken into two areas of research. Chapters IV and V provide the methodology and results for the semi-parametric analysis of the data, while Chapters VI and VII provide the methodology and results for the non-parametric analysis. The final chapter, Chapter VIII, summarizes the findings and provides recommendations resulting from the study along with suggestions for future research.

E. LIMITATIONS OF PREVIOUS RESEARCH

Most studies into the effects of commissioning source on promotion and retention have used logit or probit models with a binary dependent variable. The dependent variable has usually been a milestone such as whether an individual was promoted to a particular rank, or retained to a specific mark, say ten years of service.

Observation of whether an individual exceeds the retention milestone by one day or several years is unimportant in logit models. Hence, although logit models are useful in identifying important factors for achievement of the milestone, the results are not necessarily useful in determining those characteristics affecting the survival of individuals over a period of time. This is because the logit model oversimplifies the survival of individuals as either having made ten years or not, whereas, in reality, individuals are likely to have survived over the spectrum of possibilities from one day to over 30 years of commissioned service. There are alternatives to using logit models in the analysis of survival data and two of these alternative methodologies are the focus of this thesis. They are the Cox Regression Model and non-parametric methods.

1. Semi-parametric Studies

The Cox Regression Model, sometimes referred to as an example of a semi-parametric model, has become one of the most widely used methods for performing survival analysis. It has certain advantages over other regression methods; in particular, the coefficients combined with a 'risk ratio' have an interpretation without the need to calculate partial effects separately as is the case with a logit or probit model. Cox regression, which will be discussed briefly in Chapter IV, allows modeling of the actual likelihood of survival rather than the achievement of an arbitrary milestone.

The advantages of semi-parametric analyses are similar to those of parametric analyses. Specifically, these methods allow an effect to be attributed to each variable. The magnitude and statistical significance can be determined; this enables the researcher to determine the factors that affect the observed outcome. Specific advantages of the Cox Regression Model are outlined in Chapter IV.

Although parametric analysis is the preferred method of most researchers on account of its ability to determine partial effects, there are several disadvantages. First, partial effects may be subject to bias where not all of the covariates have been identified or where data cannot be obtained for some variables. A second disadvantage is the requirement of data for the identified covariates. Although this is not always an issue, obtaining data can occasionally pose its own restrictions on the analysis. Finally, for the casual observer, some models, particularly those not using ordinary least squares, can be difficult to interpret without the aid of software.

2. Non-parametric Studies

Previous studies have generally discounted the use of non-parametric methods on the basis that the influence of factors on retention or promotion cannot be easily determined. However, such studies have normally had the express purpose of identifying the influence of factors on retention and promotion and not the survival of officers as a function of time only. If the area of interest is in the survival of officers and not the reasons for their survival, then non-parametric models may represent a viable alternative.

A conclusion is often made in parametric analyses that factors shown to be significant in increasing retention or accessions should be identified and possibly exploited so that retention can be increased. This ignores the role that observations with lower levels of retention play in maintaining the required force structure. With all things remaining equal, including criteria for promotion selection, high levels of retention could result in a top-heavy force structure, pressure to raise promotion criteria, an increase in promotion-qualified personnel at lower ranks, inflated reporting, or forced attrition where the force structure cannot accommodate the increase in officer retention. The existence of observations with lower retention therefore permits the force to remain hierarchical whilst permitting attrition at lower ranks.

Unlike parametric studies, non-parametric analyses place little emphasis on the partial effects of variables and instead examine the overall behavior of groups. Characteristics that either improve or worsen retention are largely ignored in preference for what has actually occurred in the past. In other words, while the parametric models examine the individual effects of variables and can attribute statistical significance to variables in explaining observed behavior, the non-parametric models are concerned with the observed behavior itself without regard for what actually made it occur.

The main disadvantage of non-parametric models is that the effects of variables cannot easily be isolated and the impact of systematic trends in the data cannot easily be observed. As a result the researcher cannot answer questions regarding what caused or contributed to an observation. The advantages of the non-parametric models are largely in their simplicity and ability to be communicated. Additionally, these models require no assumptions of underlying distributions and do not require the acquisition of data for covariates. Further discussion of the disadvantages of non-parametric models is included in Chapter VI.

II. MARINE CORPS COMMISSIONING SOURCES

A. OVERVIEW

There are seven commissioning sources for USMC officers. Each of these sources has different prerequisites including age, experience, and level of education, and they also differ in post-commissioning aspects such as service obligation. Regardless of the commissioning source, almost all officers are required to attend TBS immediately after commissioning.[3] This chapter summarizes the literature regarding characteristics of the commissioning sources. Further detailed information including history of each source can be obtained in Finley (2002) or alternatively, O'Brien (2002).

B. UNITED STATES NAVAL ACADEMY

Graduates from USNA who choose to become Marine Corps Officers represent a significant proportion of all officers. Traditionally, one sixth of USNA graduates are selected to become Marine Corps officers regardless of the size of the graduating class. After completion of a four-year baccalaureate degree program at USNA, graduates selected for the Marine Corps attend TBS for a period of 26 weeks. Column (b) in Table 1 summarizes the USNA accession sequence.

C. NAVAL RESERVE OFFICER TRAINING CORPS

NROTC also selects one sixth of graduates for service with the Marine Corps. Unlike USNA, Midshipmen selected to attend an NROTC unit do not attend a residential military academy; rather, they are awarded scholarships at civilian institutions and receive full tuition toward their degree. After completion of the third year of a four-year baccalaureate degree program, the potential Marine Corps officer is required to attend a six-week training period at Officer Candidates School (OCS). On completion of the

[3] Occasionally, Warrant Officers who consider commissioning relatively late in their career do not attend TBS.

degree, the Marine Corps officer is required to attend TBS. Column (c) in Table 1 summarizes the NROTC accession sequence.

D. PLATOON LEADERS COURSE

PLC provides the highest proportion of Marine Corps officers and is open to those who are studying for a degree through an accredited university. PLC candidates who enroll in the PLC program during their freshman year are required to attend two six-week OCS training periods. Candidates who enroll after the freshman year are required to attend a ten-week OCS training period. Column (d) in Table 1 summarizes the PLC accession sequence.

E. OFFICER CANDIDATE COURSE

OCC traditionally provides the second highest proportion of Marine Corps officers and is open to those who have graduated or are in their senior year of study at an accredited university. OCC candidates are required to attend one ten-week OCS training period. Column (e) in Table 1 summarizes the OCC accession sequence.

F. MARINE CORPS ENLISTED COMMISSIONING EDUCATION PROGRAM

MECEP is intended to commission those enlisted Marines who have been identified as performing at an outstanding level. The MECEP program sponsors candidates for attendance on a full-time degree program while also receiving full pay and allowances. MECEP candidates are attached to NROTC units while they study for their degree and are required to attend a six-week training period at OCS. Column (f) in Table 1 summarizes the MECEP accession sequence.

G. ENLISTED COMMISSIONING PROGRAM

ECP provides an avenue through which qualified enlisted Marines can apply for OCS and subsequent attendance at TBS. Candidates applying for the ECP are required to possess a four year baccalaureate degree. Column (g) in table 1 summarizes the MECEP accession sequence.

H. MERITORIOUS COMMISSIONING PROGRAM

MCP provides the smallest number of officers of all commissioning sources. The program provides an avenue through which commanding officers can nominate highly qualified Marines for attendance at OCS and subsequent attendance at TBS. These officers are not initially required to posses a degree or to enroll in a program prior to commissioning; however, they are required to continue the pursuit of a degree. Column (h) in Table 1 summarizes the MECEP accession sequence.

Table 1. Summary of USMC Accession Sequence for Each Commissioning Source

	USNA	NROTC	PLC	OCC	MECEP	ECP	MCP
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Exclusive to Enlisted personnel					✓	✓	✓
Selected before degree commenced	✓	✓			✓		
Selected during freshman/sophmore			✓				
Selected during junior year			✓				
Degree obtained before selection				✓		✓	
Six-week OCS course		✓			✓		
2 x six-week OCS course			✓				
Ten-week OCS course			✓[4]	✓		✓	✓
Attendance at 26-week TBS	✓	✓	✓	✓	✓	✓	✓
Minimum service obligation	5 years	3 1/2 years	3 years	3 years	4 years	3 years	3 years

[4] Law program members or those enrolling during or after junior year are required to attend ten-week course.

I. CONCLUSION

As shown in Table 1, the commissioning sources differ significantly in the accession sequence. The impact of the differences between the sources on retention and promotion behavior has been explored in other studies, some of which are discussed in the Literature Review in Chapter III. The table does not indicate other inherent differences in the officers themselves. For example, the basic requirements of an USNA applicant include that he or she not be married, have no dependents, and not be older than 23 years of age. Such restrictions are not applicable, or appropriate, to other commissioning sources including the exclusively enlisted commissioning sources MECEP, ECP and MCP. However, some non-USNA sources have other restrictions including attendance at universities, Grade Point Average prerequisites, different age windows for attendance, and sometimes an existing military record of good performance.

III. LITERATURE REVIEW

A. OVERVIEW

The literature regarding retention of USMC personnel has been steadily growing since the development of relatively robust data files. More recently, several studies have been conducted using a data set that has been developed using all Marine Corps officers over the last two decades. Each study has had its own particular focus which varies slightly from the focus of this thesis. However, some of the findings have particular relevance in identifying potential factors which may be important in developing models for this thesis. The information provided in this chapter is intended as a brief overview of the methodologies and relevant findings in the literature.

B. LITERATURE DISCUSSION

1. Non-military Studies on Turnover Rates

Literature regarding military retention and turnover is almost exclusively conducted by military agencies or agencies contracted to perform analyses on the behalf of the military. Turnover is, however, a more general topic and many insights pertaining to the military can be drawn from the numerous studies in areas outside the military.

Examinations of factors that affect turnover in the civilian sector often arrive at similar conclusions. Cotton and Tuttle (1986) conducted a meta-analysis of 131 studies of turnover rates. The variables included in the meta-analysis consisted of three broad types: external variables, internal variables, and personal variables. The external variables included factors such as unemployment rates, vacancy rates, and organizational size. The internal variables included measures of performance, pay, and job satisfaction. Personal variables included age, gender, education, marital status, and 'biographical' information.

The meta-analysis found that almost all variables were significant to some extent. Relevant to this thesis, the meta analysis found that age, tenure, education, number of dependents and 'biographical' information were all highly significant (p-value <0.01). Furthermore, the study found that age, tenure, and number of dependents were negatively related to turnover. Gender was also significant (p-value <0.01) and was found to have a positive effect on turnover, that is, females are more likely to leave than men. Marital status was also found to be significant (p-value <0.01) with married people being less likely to leave than singles.

Several of the findings of Cotton and Tuttle are well documented and accepted in the analysis of turnover and in labor economics. For example, it is widely recognized that women have higher rates of turnover than men.[5] It is also argued that the quality of job matches rise as the age of the employee increases, hence the older an employee, the lower the turnover rate.[6]

The significance of many other variables is also well documented. Worker mobility is known to be affected by wage differentials whereby an employee is more likely to move from a low-paying job to a high paying job, all else equal.[7] Additionally, it has been observed that as the unemployment rate increases, worker mobility decreases, because people are less likely to enter a job market where there are relatively few jobs available for those seeking employment.[8]

Studies indicate that the implications for the military of many of the factors discussed so far are similar to those for the civilian community, although the magnitude may differ. The impacts on the military of many of the economic factors are summarized by Warner and Asch (1995). It is found that high unemployment rates in the civilian sector have a significant positive affect on reenlistment rates, or lower first-term attrition.[9] Whether this finding can be generalized to reenlistment decisions beyond the first term is uncertain. Warner and Asch also summarize findings that pay and bonuses are consistently found to have a positive effect on retention, or negative effect on attrition.[10] Warner and Asch focused much of their research on the economics of military

---

[5] Ehrenberg and Smith, *Modern Labor Economics* (Addison Wesley, 2002), 333-334.

[6] Ibid., 332.

[7] Ibid., 333.

[8] Ibid., 334.

[9] Warner and Asch, *The Economics of Military Manpower* (1995), 366.

[10] Ibid., 365-366. Pay and Bonuses are normally incorporated in an Annualized Cost of Leaving (ACOL) model which attempts to quantify the differential between remaining in the military or leaving.

manpower, rather than the effects of individual characteristics on turnover per se. The following studies discussed in this Chapter examine the effects of many of the personal variables on attrition.

2. Study by North and Smith (1993)

North and Smith (1993) examined officer accession characteristics and success at OCS, success after commissioning, and success at The Basic School. Using ordinary least squares they produced two separate models for the class standing on graduation from TBS and attrition from OCS as a function of age, race, SAT score, college major, prior service, marital status, and commissioning source.

The results of the study showed that the most significant factor positively affecting success at OCS was prior Marine enlisted experience. They also found minority status had a significant negative effect on success at TBS along with being female and graduating from OCC or PLC (NROTC was the base). Conversely, being married, having a science or technical college major, higher SAT score, and graduating from ECP or USNA (NROTC base) had a significant positive effect on TBS class rank.

3. Study by Quester and Hiatt

Quester and Hiatt (2001) conducted some simple diagnostic analysis of the results of the different entry sources on retention and attrition. The results are inconclusive; the five-year continuation percentages (i.e. the percentage of commissioned officers who are still in the USMC five years after commissioning) by commissioning source are detailed in Table 2.

Table 2. Five Year Continuation Rates by Commissioning Source

Commissioning Source	**5 year continuation**
Platoon Leader Course (PLC)	74.5%
Officer Candidate Course (OCC)	67.2%
Naval Reserve Officer Training Course (NROTC)	77.3%
United States Naval Academy (NSNA)	91.4%
Marine Corps Enlisted Commissioning Education Program (MCECEP)	91.8%
Enlisted Commissioning Program (ECP)	74.1%

What this preliminary study doesn't show is the relative sizes of the commissioning sources or the number of prior-enlisted officers who were commissioned through sources other than MECEP and ECP. Additionally, the payback period for all commissioning sources is at least three years; hence analyzing the continuation at just five years may not accurately show the retention propensity of individuals from commissioning sources. Therefore, attempts at generalizing from the above table about prior-enlisted officer longevity based on MECEP and ECP five-year continuation rates are not conclusive.

Quester and Hiatt also examined the continuation rate when officers were divided into three groups based on overall TBS class rank. Although a gross aggregation, this division clearly showed that officers in the top third of their TBS class were more likely to continue than those in the bottom third with continuation percentages of 82.5% and 67.6% respectively. Although Quester and Hiatt suggest that TBS rank is a good predictor of retention, whether a particular commissioning source or enlistment background dominated any of these three TBS groups, cannot be observed from their results.

4. Study by O'Brien (2002)

O'Brien (2002) analyzed the determinants of Marine Corps officers achieving ten years of commissioned service by commissioning program. Using the Marine Corps Commissioned Officer Accession Career (MCCOAC) data file between 1981 and 1999, O'Brien found that officers commissioned through OCC and PLC are less likely to remain on active duty until the ten-year mark when compared with those from the USNA. In contrast, officers commissioned through MECEP have an increased likelihood of lasting to 10 years. However, as O'Brien points out, MECEP is highly selective. Participants have already proven themselves to have the necessary attributes of an officer and have several years of service prior to commissioning.

O'Brien was unable to determine the effect of being prior enlisted on the retention of officers. At the time of his study, there was insufficient data to identify prior and non-prior enlisted officers who had accessed through commissioning sources such as PLC, OCC, USNA or NROTC. He states "Had there been a data field to provide previous service data, a more detailed analysis of the effects of prior enlisted experience on officer retention behavior could have [been done] to determine the potential benefits to the officer corps".[11] O'Brien also found that marital status, TBS graduation rank, and occupational field were significant in predicting retention to ten years.

5. Study by Finley (2002)

Finley (2002), using some of the same data as O'Brien (2002), examined the success of Naval Academy graduates at The Basic School (TBS). Although the focus was on the effect of attendance at Officer Candidates School (OCS) on success at TBS, it was identified that those with prior enlisted Marine experience were likely to perform better at TBS. Additionally, it was found that race was significant, with whites performing better than other races. Finley also provided a detailed summary of the commissioning sources that has subsequently been cited by other related studies.

6. Study by Ergun (2003)

Ergun (2003), with the same data set used by O'Brien (2002), provided additional research focusing on promotion, retention, and performance. His retention results supported the results of O'Brien in finding that PLC and OCC had a negative effect on ten-year retention and MECEP had a positive effect (compared with USNA). However, unlike O'Brien, Ergun was able to identify all prior-enlisted officers and found that prior enlisted officers were more likely to retain to ten years than non-prior enlisted officers.

Ergun was also able to show that marital status, age at commissioning, gender, TBS graduation rank, occupational field, and race/ethnic groups were significant in predicting retention to ten years. Married officers were 7.7 percent more likely to be retained to ten years than non-married officers and officers commissioned at an older age were also more likely to be retained. Women and blacks were found to be less likely to be retained.

[11] William O'Brien, *The Effect of Marine Corps Enlisted Commissioning Programs on Officer Retention,* (Master's Thesis, Naval Postgraduate School, 2002), 59.

7. Study by Bowman (1995)

The studies reviewed above have been concerned with quantitative analysis of retention or promotion. A further dimension to this thesis mentioned earlier in Chapter I is the cost-effectiveness of the commissioning sources. Although the literature regarding cost-effectiveness has been conducted using Navy commissioning sources, some of the findings and methodology are relevant to the Marine Corps.

William R. Bowman, in his paper "Cost Effectiveness of Service Academies, New Evidence from Navy Warfare Communities" (Bowman 1995) proposed methodology for determining the cost-effectiveness of Navy commissioning sources which involved taking into account the steady state accessions required to replace losses. The basis of the analysis was that officers from each commissioning source had a different number of accessions required to maintain the force structure (i.e. prescribed number of career officers). His results show that although USNA graduates cost more on average, they are also more likely to remain on active duty. Therefore, on balance, USNA graduates are actually more cost-effective despite their higher pre-commissioning costs.

8. Study by Bernard and Mehay (2003)

Bernard and Mehay (2003) expanded Bowman's (1995) study by examining the effect of each Navy commissioning program on retention and promotion with particular focus on the cost effectiveness of each program. The study differed from previous studies in that consideration was given to the marginal cost of commissioning programs rather than the average cost per officer contract. The results generally concurred with the earlier results of Bowman (1995) that "…USNA is the most cost-effective commissioning program for meeting future accession increases" for most communities with the exception of the Surface Warfare Community where Reserve Officer Training Course (Contract) is the most cost-effective.[12]

---

[12] Bernard et al, *An Analysis of Alternate Commissioning Programs for Navy Officers,* table 37.

C. CONCLUSION

The literature rarely conflicts in the findings of those factors significant in predicting Marine Corps officer retention. Some of these factors affecting retention are not unique to the military, such as marital status, gender and unemployment rate. Other factors such as commissioning source, prior enlisted experience, and TBS graduation rank are uniquely military. The literature provides a good indication of the variables that should be included in any model attempting to determine the factors that affect retention.

The studies of cost-effectiveness show that different accession sources are more cost-effective for different occupations than other accession sources. However, in general, it was found that when marginal rather than average attrition costs are considered, the USNA is often the most cost-effective despite its high average costs. The findings on cost-effectiveness suggest that on average, prior enlisted officers are unlikely to cost the same as non-prior enlisted officers.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. METHODOLOGY FOR THE SEMI-PARAMETRIC MODEL

A. OVERVIEW

The first research question in Chapter I asks: what effect does being a prior enlisted Marine have on officer longevity, *ceteris paribus*? This chapter discusses the methodology used to analyze the effect of prior enlisted status on officer longevity. The next chapter, Chapter V, discusses the results of the models detailed in this chapter.

Incorporated in this chapter is a very brief overview of the Cox Regression Model. The mathematical theory behind the Cox Model is detailed and often complicated. As a result, and in the interests of brevity, this thesis will not provide the intricacies of the model itself.[13] However, it is useful to provide a brief background on the fundamentals of the model to enable a better understanding of the coefficients it provides. After discussion of the Cox Model, the methodology, data, and assumptions used in developing the semi-parametric model for USMC retention are presented.

B. OVERVIEW OF THE SEMI-PARAMETRIC MODEL

1. The Cox Regression Model

The Cox Regression Model, also known as a semi-parametric model, was proposed in 1972 and has since found wide circulation in survival analysis including analyses using censored data. The method has two particular advantages over others in that it does not require the selection of an underlying distribution of survival times, and it allows the incorporation of time-dependent covariates.[14] Previous models had required the assumption of a distribution such as the exponential, Weibull, or gamma, to determine maximum likelihood estimates for survival.

In examining the careers of Marine Corps officers, it might be expected that once an initial obligation period has been completed, survival rates might follow a particular distribution such as the exponential. However, there are various events during a career,

[13] Sir David Cox proposed the method in 1972 in "Regression Models and Life Tables" (Journal of the Royal Statistical Society, Series B).

[14] Paul D. Allison, *Survival Analysis Using SAS* (SAS Publishing, North Carolina, 2003), 112.

including promotion and marriage, which might cause deviation from a known distribution. This could result in an assumed distribution being unreliable for some of the estimates. It is for this reason that the Cox Regression Model, which does not assume a distribution, could be an appropriate model for survival analysis of officers when the interest of the researcher is in the survival times and not the achievement of a particular milestone.[15]

2. Proportional Hazards Model

The Cox Regression Model combines the Proportional Hazards Model and an estimation method known as maximum partial likelihood. Theory surrounding the combination of proportional hazards and partial likelihood can become complicated; however the basic components of each of these aspects of the Cox model are relatively easy to explain.[16]

The Proportional Hazards Model states that the hazard, or probability of an event occurring at time *t*, for an individual *i* is a proportion of the hazard for any other individual *j*. This can be represented as:

$$\text{Proportional hazard} = \frac{h_i(t)}{h_j(t)} \tag{1}$$

where $h_i(t)$ is the hazard for an individual at time *t,* and

$h_j(t)$ is the hazard for any other individual at time *t*.

It is worthy of mention that the probability of an event occurring at exactly time *t* is zero; however a probability does exist for an occurrence between *t* and $t+\Delta t$. Then *h(t)* can therefore be defined as:

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr(t \le T < t + \Delta t \mid T \ge t)}{\Delta t} \tag{2}$$

where *T* is the event time for some particular individual.

When the probability of an event occurring between *t* and $t+\Delta t$ (given that the individual has already survived to time *t*) is divided by Δt, the limit of the result is the

[15] As discussed earlier, the logit model is appropriate for analyzing the achievement of a milestone. Previous studies using the same data have used ten year retention as the milestone.

[16] Paul D. Allison, *Survival Analysis Using SAS* (SAS Publishing, North Carolina, 2003), 113-115.

instantaneous probability of an event occurring at time *t* and can be interpreted as 'the number of events per interval of time'. If $h_i(t)$ and $h_j(t)$ are further defined as:

$$\begin{aligned} h_i(t) &= \lambda_0(t)\exp(\beta_1 x_{i1} + ... + \beta_k x_{ik}) \\ h_j(t) &= \lambda_0(t)\exp(\beta_1 x_{j1} + ... + \beta_k x_{jk}) \end{aligned} \tag{3}$$

where k is the number of covariates, $\lambda_o(t)$ is a baseline function, and the x's are characteristics of the individual, then the proportional hazard for an individual i against an individual j becomes:

$$\text{Proportional hazard} = \frac{h_i(t)}{h_j(t)} = \exp(\beta_1(x_{i1} - x_{j1}) + ... + \beta_k(x_{ik} - x_{jk})) \tag{4}$$ [17]

3. Partial Likelihood

However, there is rarely just one additional individual j. The general methodology used for proportional hazards which cancels out the baseline function is also used in determining the partial likelihood. To illustrate, the partial likelihood of an event occurring at time t for an individual i can be written as:

$$\text{PL} = \frac{h_i(t)}{\sum_{p=i}^{n} h_p(t)} = \frac{h_i(t)}{h_i(t) + h_{i+1}(t) + ... + h_n(t)} = \frac{\lambda_0(t)\exp(\beta x_i)}{\lambda_0(t)\exp(\beta x_i) + ... + \lambda_0(t)\exp(\beta x_n)} \tag{5}$$

where n is the number of surviving individuals in order of survival time. The denominator in this equation is the sum of the hazards of all individuals who have survived at least as long as individual i (recall that the hazard is also conditional on having survived until time t). The partial likelihood for **all** events is the product of all the likelihoods for all the individual events that are observed and can be represented as:

$$\text{PL} = \prod_{i=1}^{n} \left[\frac{\exp(\beta x_i)}{\sum_{j=1}^{n} \exp(\beta x_j)} \right]^{\delta_i} \qquad \text{for all } t_j \geq t_i \tag{6}$$

where $\delta_i = 0$ for censored observations and 1 for uncensored observations.

---

[17] The baseline function $\lambda_o(t)$ will not be discussed in any further detail as it cancels out from the proportional hazard; however discussion of the baseline is included in most texts. The β's can be estimated without specifying the baseline function.

Further discussion of the partial likelihood theory is not necessary other than to state that estimates for the coefficients β_k can now be obtained by maximizing the partial likelihood equation (6) with respect to β_k.

4. Interpretation of Coefficients

For ease of calculation, it is normal to take the logarithm of equation (6) the partial likelihood function. Subsequently, the resulting coefficients are the logarithms of the hazard ratio attributed to the covariate, and the exponential of the coefficient will give the hazard ratio. In practical terms, the hazard ratio gives the estimated percent change in the hazard for a one-unit increase in the covariate. Hence any value less than one represents a decrease in the hazard, and a value greater than one represents an increase in the hazard. The interpretation of coefficients will be detailed later in Chapter V.

5. Dealing with Ties

A problem with the likelihood equation given as equation (6) can occur when two or more events occur at the same time, or a 'tie' has occurred. For the data used in this thesis there are several instances where the months of service at separation for two individuals are the same, hence it is necessary to consider slightly different methods to deal with these occurrences. The mathematical theory to handle ties is complex and will not be discussed.[18] There are effectively four different methods to handle ties known as the Breslow, Efron, exact and discreet methods.

The Breslow and Efron methods are not as computationally complicated as the exact and discreet methods, and are intended to provide approximations for the exact method. However, because the software is available to use the exact and discreet methods, the Breslow and Efron methods were not considered. The discrete method assumes that events really occur at the same discrete time, whereas the exact method assumes that ties occur from grouping data into time periods.[19] The data used in this thesis have time periods grouped into monthly intervals; hence the exact method is better suited for this analysis.

[18] Paul D. Allison, *Survival Analysis Using SAS* (SAS Publishing, North Carolina, 2003), 127-137.

[19] Ibid., 137.

C. METHODOLOGY

1. Model Specification

The model developed for analysis combines many insights from the literature in particular, O'Brien (2002) and Ergun (2003), in the choice of the variables to be included. An important difference is the inclusion of variables for prior enlisted service and prior enlisted rank. The model also controls for the fixed effects of the year of graduation from TBS. Therefore, the functional form of the model shown below also contains dummy variables for each of the commissioning years. The hazard for an individual *i*, or $h_i(t)$, can be represented as:

$h_i(t) = \lambda_o(t) \times \exp(f($prior enlisted service, prior enlisted rank, gender, race, commissioning source, marital status, military occupation, commissioning age, TBS Performance, General Classification Test Category, year of commission$))$

where $\lambda_o(t)$ remains an unspecified baseline function.

2. Hypothesis

The major hypothesis that is tested concerns whether there is any difference in the length of commissioned service between prior enlisted and non-prior enlisted officers. That is:

H_0: The length of commissioned service for prior-enlisted officers is the same as the length of commissioned service for non-prior enlisted officers, *ceteris paribus*.

H_1: The length of commissioned service for prior-enlisted officers is not the same length of commissioned service for non-prior enlisted officers, *ceteris paribus*.

3. Hypothesized Effects

Table 3 shows the hypothesized effects of the variables given in the model specification on the longevity of an officer. The base case is a non-prior enlisted white unmarried male who graduated from USNA in 1986, completed TBS in the middle third of his class, and was assigned to a Combat Support Marine Occupation Specialty (MOS). The hypothesized effects are relative to the base case.

Based on previous military studies, it is expected that prior enlisted officers will remain in the USMC longer than their non-prior enlisted counterparts, all other factors being equal. The only commissioning source that is expected to have a positive effect on longevity compared with the USNA is MECEP based on the results of previous studies.[20] Additionally, it is expected that officers graduating in the top third of their TBS class will remain on active duty longer than those graduating in the middle third; and those in the middle third longer than those in the bottom third.

The effect of MOS is likely to vary across the categories because of the relative transferability of skills. It is hypothesized that officers who have obtained skills associated with their MOS that are easily transferable to jobs outside the military are more likely to leave the military than those with skills particularly unique to the military. For this reason it could be expected that Combat MOS officers would remain longer than Combat Support (CS) officers who would in turn stay longer than Combat Service Support (CSS) officers.

The effects of personal characteristics are expected to be similar to those in the civilian sector. In general, it has been observed that married employees tend to have increased fiscal responsibilities within the family and therefore a greater desire for job stability, hence the turnover of married employees is smaller.[21] Male employees do not generally experience the interrupted careers of their female counterparts; as a result,

---

[20] See Levent Ergun, *An Analysis of Officer Accession Programs and the Career Development of US Marine Corps Officers*, (Master's Thesis, Naval Postgraduate School, 2003), 91., and William O'Brien, *The Effect of Marine Corps Enlisted Commissioning Programs on Officer Retention,* (Master's Thesis, Naval Postgraduate School, 2002), 48.

[21] John L. Cotton and Jeffrey M. Tuttle, *Employee Turnover: A Meta-Analysis and Review with Implications for Research,* (The Academy of Management Review, Volume 11, Number 1, January 1986), 60.

being male is expected to have a positive effect on longevity.[22] It has also been observed that employees from ethnic minority groups have lower turnover rates which can be explained in some part by a smaller number of alternatives. In summary, characteristics such as being married, male, or a minority officer are expected to have a positive effect on longevity whereas unmarried, female, and non-minority officers are hypothesized to leave earlier.

Table 3. Hypothesized Effects of Variables on Officer Longevity

Variable	Hypothesized effect
Prior enlisted	+
Commissioning Source	
USNA	Base
PLC	-
OCC	-
NROTC	-
MECEP	+
ECP	-
MCP	-
Personal Characteristics	
Male	Base
Female	- (cf male)
Commissioning age	+
Married	+ cf(unmarried)
Unmarried	Base
White	Base
Black	+ (cf white)
Hispanic	+ (cf white)
Other race	? (cf white)
Career Characteristics	
Top Third of TBS Class	+ (cf middle 1/3)
Middle Third of TBS Class	Base
Bottom Third of TBS Class	- (cf middle 1/3)
General Classification Test category	+
Combat PMOS	+ (cf CS MOS)
Combat Support PMOS	Base
Combat Service Support PMOS	- (cf CS MOS)

Source: Author

22 Ehrenberg et al., 282 and 333.

A final demographic characteristic expected to have a positive effect on officer longevity is the age of the officer at commissioning. As individuals age, the opportunities by which they can identify a successful job match are increased. Subsequently, the older an individual the greater chance of a successful job match.[23] This observation is also expected to persist within USMC where it is hypothesized that the older the individual, the more likely he or she is to be certain that becoming an officer is the correct job match decision.

D. DATA

The Marine Corps Commissioned Officer Accession Career (MCCOAC) data file was obtained from the Center for Naval Analysis. It consists of data from 1980 – 1999 for all commissioned officers who attended TBS and consolidates information from several different sources as detailed in Quester and Hiatt (2001).

The data file ends in September 2000 and includes officers commissioned between 1980 and 1999 inclusive. As a result of the end date of the data collection, many observations (officers) were still serving as of September 2000 which resulted in a right-censored data file.

E. DATA LIMITATIONS

Although comprehensive in terms of the variables available for analysis, the MCCOAC file has several limitations regarding the data for this study. These limitations include censoring of the ranks included in the file, the reliability of some cohort data, the right censoring of data, and the accurate identification of voluntary and involuntary separations. This section further explains each of these limitations in more detail.

The MCCOAC Data file provides data for personnel in ranks up to Lieutenant Colonel (LTC/O-5) inclusive. Attrition rates and characteristics of officers who resign after obtaining the rank of LTC cannot be obtained using this data.

[23] Ehrenberg et al., 332.

Information on the career as an enlisted member before commissioning is not available prior to 1986 for officers enlisting through MECEP and ECP. Although we know that all officers entering through MECEP and ECP were prior enlisted, we do not know details such as what rank they were prior to commissioning or enlistment/promotion dates. This missing data effectively means that some models cannot be applied to officers who were commissioned prior to 1986. To allow models to be relevant for all cohorts, data are analyzed only for officers commissioned between 1986 and 2000 inclusive.

The total sample from 1986 - 2000, including prior enlisted, non-prior enlisted, separated and serving personnel is 18,464. Data prior to 1986 is not considered reliable. Of the 18,464 personnel, 7,586 had separated and the remaining officers were still serving as at September 2000.

This study does not distinguish between voluntary and involuntary separations. It is assumed that involuntary separations (post-commissioning) can be observed as random events, and do not affect either prior enlisted or non-prior enlisted officers disproportionately. This omission should create only minimal bias.

F. VARIABLE DESCRIPTION

Table 4 shows the variables used in this thesis. The dependent variable used in the model is the number of months of commissioned service (num_mon). The MCCOAC data file has rounded months down to the nearest completed month. The resulting number of months is therefore recorded as a whole number.

Many variables used in the model are self-explanatory and bivariate in nature. Such variables include gender, commissioning sources, highest enlisted rank, marital status, and race. Other variables require further explanation.

Three binary variables were created representing broad categories of the final class position in which an officer graduated from TBS. The variable TBS_1_TH identifies all those officers who finished within the top third within their cohort. TBS_2_TH and TBS_3_TH identify those ranked in the middle and bottom third of their cohort.

The data contain over 80 Primary MOS categories. Models using all of these MOS categories would be cumbersome. Personnel were therefore identified as belonging to a Combat, Combat Support (CS), or Combat Service Support (CSS) occupation field. For commonality, the MOS categories identified for each occupation field are the same as those used by O'Brien (p 61). These are indicated in Table 5.

Marital Status is recorded several times for each individual in the data set, at various stages in his or her career. The first record of marital status in the data is the status at the first record as an officer, or shortly after completion of the respective commissioning program. Because marital status often changes during a career, and some commissioning sources restrict their officers to remaining unmarried during training, it is likely that the first record of marital status may not provide accurate information regarding the effect of marital status. As a result, rather than using the first record of marriage, the marital status used for analysis is the last recorded marital status. It is assumed that any effect on longevity due to marriage is more likely to be influenced by current marital status rather than marital status immediately after commissioning.

Aside from the dependent variable, there are three other non-binary covariates. Commissioning age (comm_age) represents the age of the officer at his or her last birthday, in whole years at commissioning. The Months of service before commissioning date (prior_enlisted_months) is the number of months as an enlisted member before commissioning and includes time spent in preparation for TBS and time at TBS. This variable was rounded to the nearest whole month. The final non-binary variable is commissioning fiscal year (comm_FY) which is the fiscal year during which an officer was commissioned.

Table 4. Variable Description

Variable	Description	Type
NUM_MON	Number of months since commissioning date	Interval
	Prior Enlisted Status	
Prior_enlist	=1 if prior enlisted, =0 if non-prior enlisted	Binary
Rank_E1	=1 if highest prior enlisted rank is E1, 0 otherwise	Binary
Rank_E2	=1 if highest prior enlisted rank is E2, 0 otherwise	Binary
Rank_E3	=1 if highest prior enlisted rank is E3, 0 otherwise	Binary
Rank_E4	=1 if highest prior enlisted rank is E4, 0 otherwise	Binary
Rank_E5	=1 if highest prior enlisted rank is E5, 0 otherwise	Binary
Rank_E6	=1 if highest prior enlisted rank is E6, 0 otherwise	Binary
Rank_E7	=1 if highest prior enlisted rank is E7, 0 otherwise	Binary
Rank_E8	=1 if highest prior enlisted rank is E8, 0 otherwise	Binary
Rank_E9	=1 if highest prior enlisted rank is E9, 0 otherwise	Binary
	Commissioning Source	
PLC	=1 if commissioning source is PLC, 0 otherwise	Binary
OCC	=1 if commissioning source is OCC, 0 otherwise	Binary
NROTC	=1 if commissioning source is NROTC, 0 otherwise	Binary
MECEP	=1 if commissioning source is MECEP, 0 otherwise	Binary
USNA	=1 if commissioning source is USNA, 0 otherwise	Binary
ECP	=1 if commissioning source is ECP, 0 otherwise	Binary
MCP	=1 if commissioning source is MCP, 0 otherwise	Binary
	Personal Characteristics	
Female	=1 if female, 0 if male	Binary
COMM_AGE	Age at 1st commission	Interval
Married	=1 if married on first record as officer, =0 if not married on first record	Binary
L_mar	=1 if married at last known rank, =0 if unmarried at last known rank	Binary
White	=1 if White, =0 if non-white	Binary
Black	=1 if Black, =0 if non-black	Binary
Hispanic	=1 if Hispanic, =0 if non-hispanic	Binary
Other_race	=1 if other race, = 0 if black, white or hispanic	Binary
Non-white	=1 if Hispanic, black or other minority, =0 if white	Binary
	Career Characteristics	
TBS_1_TH	=1 if TBS score is in top third of class, =0 if middle or bottom third	Binary
TBS_2_TH	=1 if TBS score is in middle third of class, =0 if top or bottom third	Binary
TBS_3_TH	=1 if TBS score is in bottom third of class, =0 if top or middle third	Binary
GCT_CAT	GCT Category, GCT score less than or equal to 125 = 0, greater than 125 =1	Binary
Prior_enlisted_mo	Months of service before commissioning date	Interval
Combat_PMOS	=1 if PMOS is combat occupation [24], =0 if CSS or CS	Binary
CS_PMOS	=1 if PMOS is combat support occupation, = 0 if combat or CSS	Binary
CSS_PMOS	=1 if PMOS is combat service support occupation, =0 if combat or CS	Binary
COMM_FY	Year of commissioning	Interval
	Censored Variable	
Attrited	=1 if member separated prior to September 2000, =0 if still in on Sept 2000	Binary

Source: Author

[24] For comparison of results the classification of occupations was adopted from O'Brien, appendix A.

Table 5. Primary Military Occupational Specialties Assigned to Occupational Field

MOS	Description	MOS	Description
Combat Arms Occupational Group			
03XX	Infantry	08XX	Artillery
18XX	Tank and Assault Amphibian Vehicle		
Combat Support Occupational Group			
02XX	Intelligence	05XX	Marine Air Ground Task Force Plans
13XX	Engineer, Construction, Facilities and Equipment	21XX	Ordnance
23XX	Ammunition and Explosive Ordnance Disposal	25XX	Operational Communications
26XX	Signals Intelligence / Ground Electronics	60/61XX	Aircraft Maintenance
63/64XX	Avionics	65XX	Aviation Ordnance
72XX	Air Control / Air Support / Anti-air Warfare / Air Traffic Control	73XX	Navigation Officer / Enlisted Flight Crews
75XX	Naval Pilots / Naval Flight Officers		
Combat Service Support Occupational Group			
01XX	Personnel and Administration	04XX	Logistics
06XX	Command and Control Systems	11XX	Utilities
28XX	Ground Electronics Maintenance	30XX	Supply Administration and Operations
31XX	Traffic Management	33XX	Food Service
34XX	Financial Management	35XX	Motor Transport
40XX	Data Systems	41XX	Marine Corps Exchange
43XX	Public Affairs	44XX	Legal Services
46XX	Visual Information	55XX	Music
57XX	Nuclear, Biological and Chemical	58XX	Military Police and Corrections
59XX	Electronics Maintenance	66XX	Aviation Logistics
68XX	Meteorological and Oceanographic (METOC) Services	70XX	Airfield Services

Source: O’Brien (2002)

G. MODEL ASSUMPTIONS AND LIMITATIONS

1. Cox Regression Assumption

Use of the Cox Regression Method requires the assumption that the hazards are proportional over time. That is, the hazard ratio is constant over the survival time, which implies that the cumulative hazard function will increase in a straight line. The software used in this analysis (SAS) provides a graphical function which allows the survival rates (and log survival rates) to be observed. If a plot of the logarithm of the survival rates is a straight line, the hazard is constant. When this plot is created for the data, both at the aggregated and MOS level, it is observed that after the initial obligation period, the hazard does appear to be constant.

2. Data Assumptions

In addition to the assumption of constant hazard function, several other assumptions are necessary concerning the data itself. Specifically, two of the binary variables (marital status and MOS) can change during a career. Marital status may include a divorce or even subsequent marriages, and MOS can change with transfers between occupations.

As mentioned earlier, the marital status used was the last recorded as it was found to contain the lowest number of missing values. Marital status can change over time however it is assumed that the effect of marriage on longevity can best be measured by identifying those officers who were recorded as married on their most recent record.

It is also possible that officers may transfer between one or more MOS categories during their career in an attempt at job matching within the USMC. The occurrence of a MOS change is expected to be very small for prior enlisted officers as they are more likely to have already changed into the MOS for which they are best suited either before or on commissioning. The occurrences may be slightly larger for non-prior enlisted officers who have not had the same opportunity to seek a suitable job match within the USMC. The MOS used was the last recorded, as it is assumed that any effect attributable to MOS would be as a result of the last MOS. It is not expected that previous MOS would influence the retention decision of an individual significantly.

THIS PAGE INTENTIONALLY LEFT BLANK

V. RESULTS OF THE SEMI-PARAMETRIC MODEL

A. PRELIMINARY ANALYSIS

Most tables in this section show the difference in length of commissioned service between prior and non-prior enlisted officers, for those officers who have separated.[25] It should be recognized that the tables do not control for the effects of other variables, hence not all of the effects reported in the table are due solely to the variable examined. Additionally, it is obviously not possible to report the length of commissioned service at separation for those still serving, hence large amounts of data have been censored from some tables.

1. Commissioning Source

Table 6 provides the percentage breakdown of the total sample of 18,464 officers by commissioning source (numbers in parentheses). All officers commissioned through the MECEP, ECP and MCP programs are prior enlisted. The table indicates that 34.09 percent of the sample is prior enlisted. The main commissioning source for prior enlisted officers is OCC (45.76 percent) followed by PLC (21.16 percent). The main commissioning source for non-prior enlisted officers is PLC (41.32 percent) followed by NROTC (26.86 percent). Overall, PLC, OCC and NROTC commission almost 79 percent of all Marine Corps officers.

[25] Censored data is not included in the calculations of length of commissioned service during this Preliminary Analysis.

Table 6. Percentage of USMC Officers from Commissiong Sources

Commissioning Source	Percent (%) of Prior enlisted Personnel	Percent (%) of Non-prior enlisted personnel	Percent (%) of total sample	Percent (%) of those separated
(a)	(b)	(c)	(d)	(e)
Other	0.33 (21)	0.42 (51)	0.39 (72)	0.20 (15)
PLC	21.16 (1330)	41.32 (5034)	34.47 (6364)	38.12 (2892)
OCC	45.76 (2874)	14.62 (1780)	25.21 (4654)	24.68 (1872)
NROTC	4.49 (282)	26.86 (3270)	19.24 (3552)	22.04 (1672)
MECEP	13.06 (820)	-	4.44 (820)	1.77 (134)
ECP	10.37 (653)	-	3.54 (653)	3.06 (232)
USNA	1.32 (83)	16.28 (1982)	11.18 (2065)	9.44 (716)
MCP	3.26 (205)	-	1.11 (205)	0.08 (6)
n	34.09 (6268)	65.91 (12117)	100.00(18385)	100.00 (7539)

Source. MCCOAC Data, missing data = 79 from total (15 prior enlisted, 64 non-prior enlisted), 47 from separated.

2. Length of Commissioned Service

Column (d) in Table 7 shows the average number of commissioned months for each of the commissioning sources for those officers who have separated. Overall, the average length of commissioned service was over 72 months; however there was a large difference between commissioning sources. MECEP officers have the longest length of service of over 92 months while MCP officers have the shortest length of service of just 46 months (although the separated MCP officers in the sample number only six).

Columns (b) and (c) show the length of commissioned service for prior enlisted and non-prior enlisted officers respectively. The number of officers in each group is indicated in parentheses. Aside from MCP officers having a relatively short length of service, it is noted that all other commissioning sources have average lengths of service at least 17 months less than MECEP officers. The variation among the non-prior enlisted commissioning sources is not as large with fewer than 17 months separating OCC, which was the source with the shortest average length of service of almost 66 months, from USNA which had the longest average length of service of over 82 months.

It is evident from Table 7 that for those commissioning sources accepting both prior and non-prior enlisted officers, prior enlisted officers remain in the USMC as officers for a shorter period of time. Across the commissioning sources, prior enlisted officers have a length of commissioned service between six and nine months shorter than non-prior enlisted officers, for those officers who have separated.

Overall, there appears to be a 10 month difference between the length of commissioned service of prior enlisted and non-prior enlisted officers. However, the practical significance of this figure, and the potential influence of the censored data (i.e. those personnel not yet separated), means no firm conclusions can yet be drawn. In practical terms, 10 months may not be a significant enough time difference to dramatically affect manpower planning and necessitate differentiating between prior and non-prior enlisted. Importantly, there are large numbers of officers who are currently serving whose length of service has not been incorporated into the average length of service; hence some or all of the 10 month difference may be explained either by other factors, or by the censored data.[26]

Table 7. Length of Commissioned Service by Commissioning Source for Separated Officers (1986-1999)

Commissioning Source	**Avg length of commissioned service Prior enlisted** (months)	**Avg length of commissioned service Non-prior enlisted** (months)	**Avg length of commissioned service for all separated officers** (months)
(a)	(b)	(c)	(d)
Other	38.00 (9)	55.67 (6)	46.06 (15)
PLC	69.26 (378)	75.60 (2510)	74.77 (2888)
OCC	58.64 (974)	65.81 (897)	62.08 (1871)
NROTC	66.06 (78)	74.98 (1593)	74.57 (1671)
MECEP	92.16 (134)	-	92.16 (134)
ECP	62.92 (230)	-	62.92 (230)
USNA	75.00 (18)	82.49 (697)	82.31 (715)
MCP	46.33 (6)	-	46.33 (6)
	64.17 (1827)	74.71 (5703)	72.15 (7530)

Source. MCCOAC Data, missing data = 56.

26 The sample reveals that of the 6820 prior enlisted officers, 73.1 percent still remain. In contrast, of the 12,170 NPE officers, 52.8 percent still remain; this amount of censored data has a large impact on the results. For example, the table indicates that MCP officers have a very short length of commissioned service; however, of the 205 MCP officers, only 6 have separated.

3. Gender

The difference in length of commissioned service by gender is detailed in Table 8. The length of service of females is almost nine months less than males on average. The distribution of females into their prior enlisted and non-prior enlisted groups shows that in both groups length of commissioned service is five to seven months less for females than for males (numbers are shown in parentheses). The practical significance and effect of censored data is unknown; however the figures show tentative support for the literature in regard to female turnover resulting from interrupted careers.

Table 8. Length of Commissioned Service by Gender for Separated Officers (1986-1999)

	Avg length of commissioned service Prior enlisted (months)	**Avg length of commissioned service Non-prior enlisted** (months)	**Avg length of commissioned service for all separated officers** (months)
Male	64.62 (1674)	78.85 (5515)	75.54 (7189)
Female	59.53 (161)	71.83 (223)	66.67 (384)
Total	64.17 (1835)	78.57 (5738)	72.17 (7573)

Source. MCCOAC Data, missing data =13.

4. Age Distribution

Table 9 shows the average commissioning age for prior and non-prior enlisted officers (numbers are shown in parentheses). The entire sample of 18,464 officers can be used to calculate these figures. The average commissioning age is 23.56 years while the average commissioning age of prior and non-prior enlisted officers is 25.11 and 22.75 years respectively, a difference of 2.36 years. As anticipated, the commissioning age of the exclusively prior enlisted commissioning sources (MECEP, ECP and MCP) is higher than for other sources. Additionally, within USNA, NROTC and PLC, prior enlisted officers are commissioned at an older age than non-prior enlisted.

Table 9. Commissioning Age of USMC Officers by Commissioning Source

Commissioning Source	Avg age when commissioned Prior enlisted (years)	Avg age when commissioned Non-prior enlisted (years)	Avg age when commissioned (years)
(a)	(b)	(c)	(d)
other	26.19 (21)	22.16 (51)	23.33 (72)
PLC	23.78 (1318)	22.69 (4987)	22.92 (6305)
OCC	24.84 (2849)	24.30 (1766)	24.63 (4615)
NROTC	24.15 (272)	22.24 (3156)	22.40 (3428)
MECEP	26.91 (816)	-	26.91 (816)
ECP	26.45 (647)	-	26.45 (647)
USNA	24.74 (73)	22.28 (1825)	22.37 (1898)
MCP	25.17 (205)	-	27.17 (205)
Total	25.11 (6216)	22.75 (11843)	23.56 (18059)

Source. MCCOAC Data. Missing data = 405

5. Race

Table 10 shows the difference in length of commissioned service by race/ethnicity. Non-white officers consistently have a shorter average length of commissioned service than white officers with black officers having an average length of service over eight months less than white officers, and Hispanic officers four months less. The difference between whites and non-whites is not as it was hypothesized; however, as with other variables, the effect of censored data is unknown.

Table 10. Length of Commissioned Service by Ethnicity for Separated Officers (1986-1999)

Race/Ethnicity	Avg length of commissioned service Prior enlisted (months)	Avg length of commissioned service Non-prior enlisted (months)	Avg length of commissioned service for all separated officers (months)
White	65.30 (1514)	75.22 (4988)	72.91 (6502)
Black	55.89 (157)	69.01 (302)	64.52 (459)
Hispanic	60.88 (88)	71.88 (234)	68.87 (322)
Other race	62.64 (76)	74.47 (215)	71.38 (291)
Total	64.17 (1835)	74.73 (5739)	72.17 (7574)

Source. MCCOAC Data, missing data =12.

6. Marital Status

Table 11 gives the length of commissioned service for married and unmarried officers as defined by their last recorded marital status. It can be observed that married officers appear to remain for around 15 months longer than unmarried officers regardless of whether they were prior enlisted or not. Even though the table uses censored data, it suggests that marital status may be a significant variable in the survival analysis.

Table 11. Length of Commissioning Service by Last Recorded Marital Status Separated Officers (1986-1999)

Marital Status	**Avg length of commissioned service Prior enlisted** (months)		**Avg length of commissioned service Non-prior enlisted** (months)		**Avg length of commissioned service for all separated officers** (months)	
Married	71.86	(963)	82.61	(2698)	79.78	(3661)
Unmarried	55.68	(872)	67.74	(3041)	65.05	(3913)
Total	64.17	(1835)	74.73	(5739)	72.17	(7574)

Source: MCCOAC Data, missing data =12.

7. TBS Thirds

Table 12 shows the average length of commissioned service by TBS class rank. For both prior and non-prior enlisted officers, and overall, the average length of commissioned service decreases from the top to the bottom third. Again, prior enlisted officers have a shorter length of commissioned service than non-prior enlisted officers; however, the table is also subject to the effects of censored data.

Table 12. Length of Commissioned Service by TBS Class Rank Separated Officers (1986-1999)

	Avg length of commissioned service Prior enlisted (months)		**Avg length of commissioned service Non-prior enlisted** (months)		**Avg length of commissioned service for all separated officers** (months)	
Top Third	72.27	(479)	78.50	(1577)	77.05	(2056)
Middle Third	65.83	(558)	76.18	(1930)	73.86	(2488)
Bottom Third	58.42	(791)	70.91	(2227)	67.63	(3018)
Total	64.31	(1828)	74.77	(5734)	72.24	(7562)

Source. MCCOAC Data, missing data = 24.

8. Occupation Field

Table 13 shows the length of commissioned service by MOS category. The figures indicate that Combat and CSS officers have a much shorter length of commissioned service than CS officers. It also appears that prior enlisted officers have a shorter period of commissioned service across all three broad MOS categories. As with earlier tables, the impact of the censored data is unknown; however, the difference between CS and the other MOS categories may well be too large to be explained by censored data.

Table 13. Length of Commissioned Service by MOS Category for Separated Officers (1986-1999)

MOS Category	**Avg length of commissioned service Prior enlisted** (months)		**Avg length of commissioned service Non-prior enlisted** (months)		**Avg length of commissioned service for all separated officers** (months)	
Combat	61.83	(513)	69.69	(1670)	67.84	(2183)
CS	79.91	(352)	94.22	(1611)	91.65	(1963)
CSS	59.88	(670)	65.62	(1541)	63.88	(2211)
Total	65.13	(1535)	76.58	(4822)	72.82	(6357)

Source. MCCOAC Data. Missing data =1219 (302 prior enlisted)

9. Prior Enlisted Rank

Table 14 provides the average length of commissioned service for prior enlisted officers sorted by their highest rank prior to commissioning. The results are ambiguous showing that officers whose highest enlisted rank was E-1 or E-2 have an average length of service of over 67 months, those whose highest rank was E-3 to E-5 have an average length of service of around 61 months, and officers who reached E-6 and E-7 have much linger commissioned service of over 103 months. This may be explained in some part by the fact that E-6 and E-7 officers are older at commissioning, and therefore more likely to be associated with a good job match. Additionally they may be more likely to be closer to the 20 year milestone which may act as an incentive to remain longer than other prior enlisted ranks.

Table 14. Length of Commissioned Service for Prior Enlisted Officers by Highest Enlisted Rank

Rank	Avg length of commissioned service Prior enlisted (months)	Rank	Avg length of commissioned service Prior enlisted (months)
E1	67.39 (96)	**E5**	60.93 (1113)
E2	67.30 (167)	**E6**	103.86 (88)
E3	61.29 (204)	**E7**	128.00 (8)
E4	60.10 (153)		

Source. MCCOAC Data. Missing data = 8.

B. MODEL RESULTS

Table 15 shows the regression results using the Cox Regression Model. Three different models were explored with slight differences in the variables included in each model. The first model groups all prior enlisted officers into one category, the second model separates the prior enlisted officers into groups based on their highest enlisted rank, and the third model is a reduced form of model 1 which does not control for the commissioning year.

1. Model 1 Results

The first model indicates that, *ceteris paribus*, prior enlisted officers have a smaller hazard ratio than non-prior enlisted officers. In fact, the coefficient and hazard ratio can be interpreted to indicate that prior enlisted officers have about 94 percent of the hazard of non-prior enlisted officers, which is significant at the 0.10 level.

The commissioning sources were found to be among the most influential variables affecting the survival of officers. All commissioning sources, except MCP, were found to be highly significant (<0.01 level) when compared against the base case which was USNA. MECEP officers, as hypothesized, exhibited a hazard just 72 percent of the hazard for USNA graduates, *ceteris paribus*. Conversely, OCC graduates exhibit a hazard 173 percent that of USNA graduates indicating that their survival rate is much lower than USNA graduates.

Commissioning age and marital status were also found to be significant at all the usual levels. Married officers had a hazard of just 42 percent of that who were not married, all else being equal. This rather large effect implies that officers are much more likely to remain in the USMC when they are married. This result corresponds with discussions in the literature regarding the decreased mobility and turnover of married workers. No significant effects due to gender or race/ethnic group were identified in the model.

The interpretation of the hazard rate for commissioning age, which was also significant at all the usual levels, is somewhat different from that for binary variables. The hazard ratio of 0.966 indicates that a one-year increase in commissioning age decreases the hazard by 100(1-0.966) percent, or 3.4 percent. For example, if all other factors were the same, the difference in hazard between a 28 and a 26 year old officer at commissioning would be 6.8 percent decrease for the 28 year old.

The rank in the graduation class from TBS was found to be very significant at all the usual levels. Officers graduating in the top third of TBS had a hazard of 86 percent of the hazard of those graduating in the middle third. By contrast, officers graduating in the bottom third had an increased hazard when compared with the middle third of 124 percent. The reason for this difference should be subject to further analysis. However, it may reflect those finishing in the top third having a better job match than those in the bottom third.

The size of the hazard for officers with Combat and CSS MOS was unexpected as was the negative effect of Combat MOS on longevity, which was not the hypothesized effect. It was expected that the low transferability of combat skills to the civilian sector would result in a lower hazard for combat officers than both CS and CSS officers. Holding other factors equal, both Combat and CSS officers have a much higher hazard than CS officers of 176 percent and 200 percent respectively with coefficients significant at all the usual levels. The reasons for the large hazard rates are unclear; however aspects such as the transferability of learned skills, job satisfaction, worker fatigue, or successful job match may all be significant factors.

2. Model 2 Results

Model 2 replaced the prior enlisted variable with the highest rank prior to commissioning. The base case for the prior enlisted rank was no prior enlisted rank, in other words, non-prior enlisted officers. Only two ranks were found to be significant which may reflect in part the small practical and statistical significance of the prior enlisted variable in model 1. It was found that the hazard for a prior enlisted officer who held the rank of E-3 was 84.8 percent of the hazard for a non-prior enlisted officer, significant at the 0.05 level and holding other factors equal. The hazard for an E-4 was 82.9 percent of the hazard for non-prior enlisted officers, significant at the 0.10 level.

Holding the rank of E-5 prior to commissioning was not significant. Additionally, its hazard estimate was close to one providing evidence that the hazard rate for E-5s is no different to non-prior enlisted officers. As E-5s make up the majority of prior enlisted officers (see Table 14), the fact that prior enlisted officers in model 1 was significant may be impacted more by E-1 to E-4s, who all had hazard rates less than one, than higher ranks who all had hazard rates higher than one (although none were significant). The results suggest that the positive effects of being prior enlisted on the survival of officers apply more to those holding the rank of E-1 to E-4 rather than higher ranks.

The remaining significant hazards are very similar to the hazards found in model 1 with most results differing by less than one percent. However, MECEP officers further decreased their comparative hazard from 72 percent in model 1 to 65 percent in model 2. The hazard for OCC and ECP also decreased in comparison with model 1, but they still remain at 170 and 169 percent of the hazard for USNA graduates respectively.

3. Model 3 Results

The third model was a reduced form of model 1 which removed the fixed effect variables for the commissioning year. Most hazards are within one percent of the hazards in model 1 with the exception of the prior enlisted hazard, which decreases to 91 percent of the hazard for non-prior enlisted officers compared with 94 percent in model 1. Additionally, the significance of this variable is increased from the 0.10 level in model 1 to the 0.05 level in model 3.

Table 15. **Regression Results Using the Cox Regression Method[a]**

	Model 1		Model 2		Model 3	
Variable	**Coefficient Estimate**	**Hazard Ratio**	**Coefficient Estimate**	**Hazard Ratio**	**Coefficient Estimate**	**Hazard Ratio**
Prior enlisted	-0.06366	0.938*			-0.0923	0.912**
E1			-0.12329	0.884		
E2			-0.1245	0.883		
E3			-0.16505	0.848**		
E4			-0.18776	0.829*		
E5			0.00766	1.008		
E6			0.04084	1.042		
E7			0.31004	1.363		
Commissioning Source						
PLC	0.28432	1.329***	0.29072	1.337***	0.26975	1.31***
OCC	0.55035	1.734***	0.52874	1.697***	0.53965	1.715***
NROTC	0.18136	1.199***	0.18305	1.201***	0.18201	1.2***
MECEP	-0.32892	0.720***	-0.42473	0.654***	-0.31017	0.733***
ECP	0.55724	1.746***	0.52503	1.691***	0.55358	1.739***
MCP	-0.27773	0.758	-0.31457	0.73	-0.34143	0.711
Personal Characteristics						
Female	-0.10012	0.905	-0.11543	0.891*	-0.0985	0.906
COMM_AGE	-0.0341	0.966***	-0.03392	0.967***	-0.03744	0.963***
Married	-0.88585	0.412***	-0.88592	0.412***	-0.85882	0.424***
Black	-0.07498	0.928	-0.07254	0.93	-0.07778	0.925
Hispanic	-0.043	0.958	-0.04432	0.957	-0.05601	0.946
Other race	-0.05194	0.949	-0.04856	0.953	-0.04996	0.951
Career Characteristics						
Top TBS third	-0.15112	0.86***	-0.15089	0.86***	-0.14878	0.862***
Bottom TBS third	0.21813	1.244***	0.21707	1.242***	0.21837	1.244***
GCT category	0.03143	1.032	0.03116	1.032	0.03275	1.033
Combat PMOS	0.5636	1.757***	0.56571	1.761***	0.558	1.747***
CSS PMOS	0.69505	2.004***	0.69709	2.008***	0.69014	1.994***
comm_87	0.29824	1.347***	0.29066	1.337***		
comm_88	0.2712	1.312***	0.27408	1.315***		
comm_89	0.15319	1.166***	0.1535	1.166***		
comm_90	0.07969	1.083	0.08478	1.088		
comm_91	0.05117	1.052	0.05316	1.055		
comm_92	-0.01509	0.985	-0.02317	0.977		
comm_93	-0.12629	0.881*	-0.12538	0.882*		
comm_94	-0.07889	0.924	-0.06789	0.934		

comm_95	-0.02496	0.975	-0.01022	0.99		
comm_96	0.10716	1.113	0.11845	1.126		
comm_97	-0.10646	0.899	-0.09271	0.911		
comm_98	-0.27044	0.763	-0.26163	0.77		
comm_99	0.47032	1.6	0.48043	1.617		
n	14953		14953		14953	
-2 Log L	103204.25		103195.68		103303.70	
Likelihood Ratio	2250.78		2259.36		2151.34	

Source: Author.

a. * indicates significant at the 0.10 level, ** is significant at the 0.05 level and *** is significant at the 0.01 level

C. COMPARISON OF RESULTS AGAINST OTHER RESEARCH

The models developed by O'Brien and Ergun include some different variables; however, they can be compared with the Cox Regression Results in terms of their magnitude and significance. Hazard ratios of less than one in the Cox model should generally have coefficients with a positive (+) sign in the logit model, and ratios greater than one should have coefficients with a negative (-) sign. This reflects the positive or negative effects of variables on either retention in the logit model, or longevity in the Cox model. Similarly, variables found to be significant in the logit model may also be expected to be significant in the Cox model, although this is not always the case, particularly at low levels of significance in the logit model.

The effects attributed to a variable can also differ greatly under the logit and Cox models.[27] For example, Ergun estimates that officers graduating from PLC and OCC have ten-year retention rates three and nine percentage points lower than USNA graduates respectively. On the other hand, the Cox Regression Model implies the hazard for PLC and OCC graduates are 133 percent and 173 percent of the hazard for USNA graduates respectively. The Cox model implies the effects due to these two commissioning sources on survival are much greater than the logit effects on ten-year retention.

The difference can be explained, in part, using table 7. The logit model is only concerned with officers who do or do not make the ten-year milestone. However, some

[27] The calculation of the effects of variables under the logit model is not intuitive. In the separate studies by O'Brien and Ergun, the calculated marginal effects show the percentage point increase in ten year retention for a one unit increase in the covariate.

officers, particularly those from OCC, fall significantly short of ten years. In fact, table 7 implies they fall almost five years short of the ten year milestone on average. Similarly, PLC officers may fall around four years short of the ten year mark on average. Because the logit model does not distinguish between falling many years short or just a few days short of ten years, the effects attributed to the commissioning sources by the logit model cannot be applied to survival or longevity and may provide an inaccurate indication of the true effects.

In contrast, O'Brien attributes large significant negative effects on ten year retention for PLC and OCC graduates of 47.3 percent and 57.1 percent respectively. The magnitude of O'Brien's results are closer to the magnitude provided by the Cox regression. Furthermore, the magnitude of the positive effect of MECEP graduate status provided by O'Brien (51.0 percent) is also closer to the magnitude provided by the Cox regression.

The effects attributed to marital status vary between Ergun and O'Brien; however both have a significant positive effect on ten-year retention. O'Brien's results indicate that married officers are 47.2 percent more likely to stay until the 10^{th} year, whereas Ergun predicts it to be much smaller at 7.7 percent. The Cox regression model also indicates a strong positive effect on survival of an order likely to be closer to that of O'Brien.

All models, including the Cox regression, estimated strong effects due to class rank. O'Brien's regression indicates that those in the top third are 19 percent more likely to stay until the 10^{th} year and those in the bottom third are 46.8 percent less likely when compared to the middle third. The Cox regression provides the same ordering of the class rank.

O'Brien's model indicates that CSS officers have a large and significant negative effect on ten-year retention of 30.1 percent. The Cox model concurs with this result although the effect may be even greater than that predicted by O'Brien.

D. SUMMARY OF RESULTS FOR THE COX REGRESSION MODEL

The results indicate that although being a prior enlisted officer has a small positive effect on survival rates, there are other variables that have a much greater effect and are of more practical significance. The commissioning source was found to have a strong effect on survival rates with most commissioning sources exhibiting a negative effect on survival rates when compared with USNA graduates. The only exception was MECEP graduates.

Of the demographic characteristics, the commissioning age was found to have a small positive effect; however, the practical significance is smaller than for other effects. Marital status was found to have a very strong positive effect on survival rates with married officers exhibiting a much smaller hazard than unmarried officers.

The effect of class standing from TBS was found to have varying effects depending on the third of the class that an officer was grouped into. Those graduating in the top third of the class had a greater survival rate (smaller hazard) than those in the middle third who had a greater survival rate than those in the bottom third.

The effect of the MOS categories was much greater than expected with both Combat and Combat Service Support officers exhibiting dramatically increased hazards, or smaller survival rates, than those in Combat Support. The reasons for the significance of this result may require focused research from a sociological perspective. Table 16 provides a summary of the observed effects compared with the hypothesized effects detailed in Chapter IV.

Table 16. Summary Table of Hypothesized and Observed Effects from the Cox Regression Method

Variable	Hypothesized effect	Observed effect
Prior enlisted	+	+
Commissioning Source		
USNA	Base	Base
PLC	-	-
OCC	-	-
NROTC	-	-
MECEP	+	+
ECP	-	-
MCP	-	-
Personal Characteristics		
Male	Base	Base
Female	- (cf male)	0
Commissioning age	+	+
Married	+ cf(unmarried)	+
Unmarried	Base	Base
White	Base	Base
Black	+ (cf white)	0
Hispanic	+ (cf white)	0
Other race	? (cf white)	0
Career Characteristics		
Top Third of TBS Class	+ (cf middle 1/3)	+
Middle Third of TBS Class	Base	Base
Bottom Third of TBS Class	- (cf middle 1/3)	-
GCT category	+	0
Combat PMOS	+ (cf CS MOS)	0
Combat Support PMOS	Base	Base
Combat Service Support PMOS	- (cf CS MOS)	-

Source: Author.

THIS PAGE INTENTIONALLY LEFT BLANK

VI. METHODOLOGY FOR ACCESSION OPTIMIZATION

A. CHAPTER OVERVIEW

Although there is a large body of literature regarding the cost-effectiveness of Navy commissioning sources, little has been written on the cost-effectiveness of USMC commissioning sources. Many of the methods used by Bowman (1995) and Bernard (2003) in analyzing cost-effectiveness of Navy commissioning sources could be applied to the USMC case, particularly those cost-effectiveness methods that use marginal costs rather than average costs. However, the compilation of the necessary USMC data to obtain marginal costs is beyond the scope of this thesis and consequently the USMC commissioning source average costs are used. The focus of this and the following chapter is on the balance between the cost of each type of officer (prior enlisted and non-prior enlisted), and the accessions required to obtain the optimum number of USMC personnel from the commissioning sources.

The second research question posed in Chapter 1 asks: What is the optimal mix of prior and non-prior enlisted officer accessions such that the force structure can be maintained without resulting in vacancies at various ranks and without exceeding the fiscal budget? This chapter discusses the methodology used to determine the optimal mix of officers. The next chapter, Chapter VII, discusses the results of the model detailed in this chapter.

B. OVERVIEW OF THE NON-PARAMETRIC MODEL

The research question presents an objective function, a function of two variables (prior and non-prior enlisted officer accession numbers) that is the focus for optimization. In addition, there are two broad constraining factors on the optimal mix of officers (the objective function) that must be explored. The first is a fiscal constraint on the number of officer accessions. The second constraint is the requirement for a particular number of officers in certain ranks. There may be many other constraining factors that impact the optimum mix; however, these two are considered the most significant.

A linear form, described later in this chapter, is developed for each of the constraints. To meet the second constraint on the number of O-4's required, a non-parametric Markov model is used. The non-parametric nature of the model considers only a comparison of non-prior and prior enlisted officers as they 'survive' from one year to the next. An important difference between the parametric and non-parametric models in this thesis is that in the non-parametric model, the differences between prior and non-prior enlisted survival rates do not take into account the confounding effects of other variables such as marital status, commissioning source, etc. As a result, in the non-parametric model, only the survival behavior of officers as separated by prior and non-prior enlisted status can be observed and not the effects of any other factors shown to affect survival.

When the two constraints are applied to the objective function it is possible to develop a simple linear program. The goal of the linear program is not necessarily to minimize expenditure on officer accessions, or to maximize accession numbers; rather it is to obtain a prescribed number of officers at a particular rank using the prescribed accession budget. It is expected that the intersection of the two constraints, from both a fiscal and force structure perspective, represents a mix of officers that satisfies the requirements of both constraints and optimizes accessions with respect to the two constraints.

1. Fiscal Constraint

The fiscal constraint compares the costs and benefits of a prior enlisted officer with a non-prior enlisted counterpart. If costs for non-prior enlisted officers are higher, then at one extreme, if all officers were non-prior enlisted, we might expect higher recruiting and training costs which would imply a smaller number of officers accessed with a given budget. At the other extreme, if all officers were prior enlisted it could imply a different, and potentially lower, total accession cost with higher numbers of officers for a given budget.

Discussion and theory of the fiscal constraint are discussed in more detail in Section F of this chapter. In essence, the fiscal constraint asks "what are the possible combinations of prior enlisted and non-prior enlisted officers given a particular accession budget?"

2. Force Structure Constraint

The force structure constraint concerns the ability of the accession sources to provide sufficient quantities of personnel to the senior ranks. Chapter V indicated that separation rates for commissioning sources are different; it follows that changing the proportion of officers from each commissioning source would also change the overall separation rate.

Maintaining the force structure requires balancing separation rates such that they are neither too high nor low. The consequences of high separation rates, such as increased vacancies and decreased readiness, are generally intuitive. There are other secondary consequences such as a decrease in time-in-rank criteria for promotion resulting in faster promotion, less experienced senior officers, and a younger officer corps. Low separation rates also have consequences such as pressures on end strength, increases in time-in-rank for promotion, ageing of the officer corps, more competitive promotion and forced separations.

The theory of the force structure constraint is discussed in more detail in Section G of this chapter. The constraint asks 'what are the possible combinations of prior enlisted and non-prior enlisted officers necessary to maintain readiness, given the attrition rates for each type of accession and the force structure?'.

3. Other Complicating Factors

There are several other factors that can complicate the optimization. Not all prior enlisted officers or non-prior enlisted officers are commissioned through the same source. Although all attend The Basic School (TBS), there are several different commissioning routes they may follow prior to TBS; and therefore the cost of one prior enlisted officer will not necessarily be the same as the cost of another. Similarly, the costs for different non-prior enlisted officers will not necessarily be the same.

C. METHODOLOGY

Solving the linear programming problem described earlier obviously requires the determination of a linear form for the constraints. The precise methodology for determining each constraint is detailed later in this chapter while general theory regarding Markov models is included in this section. Once the two constraints have been defined, linear programming techniques using spreadsheet applications (specifically Microsoft Excel Solver) can be used to find an optimal solution. Fortunately, in this specific case where there are only two constraints, it is most likely that the optimum will occur at their intersection, although this may not be the case in other linear programs.

1. Accession Possibilities Diagram

The starting point in the methodology for determining an accession optimum is recognition of an Accession Possibilities Diagram (APD). The APD represents the possible theoretical combination of prior and non-prior enlisted officer accessions into the USMC. Without any constraints on accessions whatsoever, any combination of prior and non-prior enlisted officers is possible. The lack of constraints is, however, unrealistic. At the most elementary level, the number of accessions is restricted by the number of people who would pass the USMC officer selection criteria, and those who would wish to become USMC officers. Figure 1 shows the most basic APD without constraints for which any combination is possible. The points simply represent examples of accession possibilities from either prior or non-prior enlisted officers.

Figure 2 represents the same APD but introduces two constraints.[28] Should these lines represent the fiscal and force structure constraints, an optimal point may be represented by their intersection, *Z*. The bold sections of the line represent other possible solutions that adhere to both constraints although any point along the bold lines would not be an optimal point. Any point outside the bold lines would not be a feasible solution even if it fell within one of the constraints. All feasible solutions reside between the origin and the bold lines as indicated by the shaded area.

[28] The diagram shows that the constraints have intercepted both with each other and the axis however this is not necessarily the case. In the simplest solvable linear program the two constraints do intercept.

Practical values for USMC officer accessions must be considered. Although the intersection of the bold lines with the horizon may be theoretically possible ‘optimal’ solutions in terms of the linear program, they would not have a basis in reality. The range over which the constraints are valid is discussed in the next chapter; however, as a precursor, it is unrealistic to expect the constraints to be linear over the entire range of possibilities.

The fiscal and force structure constraints for officer optimization will be discussed in more detail in Sections F and G respectively. A model for determination of the fiscal constraint does not warrant discussion prior to Section F, however discussion of the model for determination of the force structure constraint, namely a Markov model, is appropriate.

Figure 1. Basic Accession Possibilities Frontier Diagram

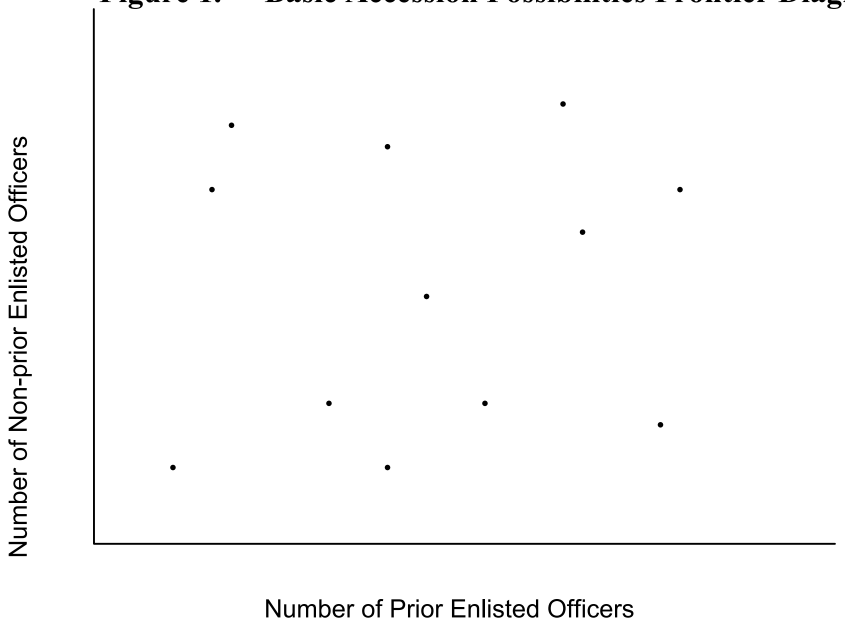
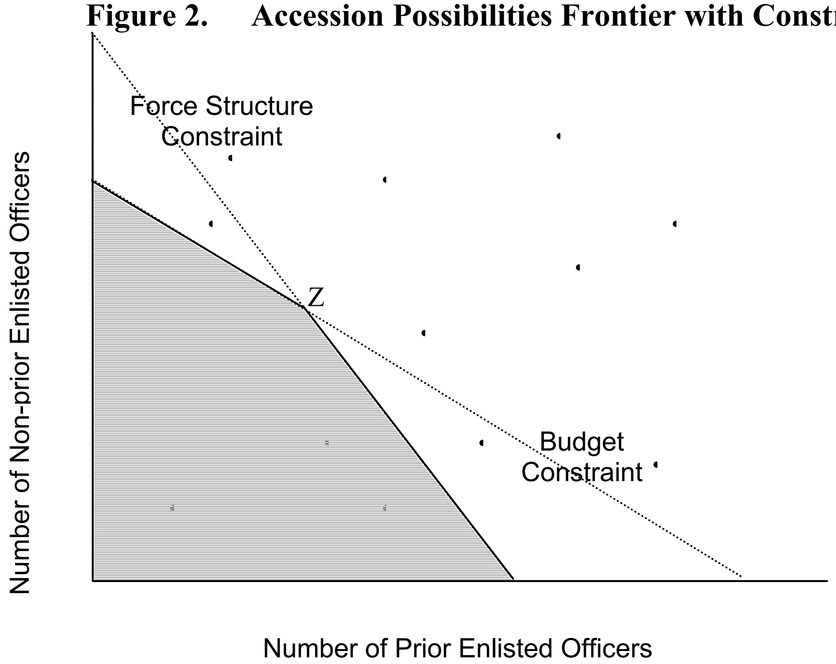


Figure 2. Accession Possibilities Frontier with Constraints



Source: Author

2. Markov Model Specification

The data used for the non-parametric model, and described in Section D of this chapter, allow for the construction of a Markov-type transition matrix with absorption. The transition matrix identifies the proportion of personnel who transition from one 'state' to another. In the case of an officer career transition matrix, the 'state' could be represented by a year of service (YOS) in which case the transition is the proportion of personnel who transition from their first YOS to a second YOS and so on. Alternatively, a 'state' could represent a rank and the transition would be the subsequent proportion of officers who are promoted from a rank into the next rank. The 'absorption' state refers to separation.

It is generally possible to determine a 'steady state' of the Markov model which is the situation where the number of personnel transitioning from one state to another is the same when comparing consecutive time periods *t* minus *1* to *t*. For example, a steady state for USMC officers might indicate that in any one year (*t* minus *1*) the number of officers who transitioned from their first YOS into the second was 1200, which is the same number that transitioned from their first to second YOS in the following year (*t*), assuming accessions remain constant. When this occurs for all transitions then a steady state has been achieved. The value of obtaining an estimate for the steady state is that it provides the necessary information to predict the number of officers in each YOS when the accession number remains constant. In other words, given the number of accessions in each year (and assuming it remains constant), it is possible to determine the number in each YOS, and therefore approximate the number of officers in any rank. The existence of a steady state requires several assumptions that are detailed in Section G.

The general form of the steady state for the Markov model is given by:

$$s(t) = \lambda (I - P^T)^{-1} r \qquad (7)$$

where

$s(t)$	=	'stock' or number of personnel at time t in each state
λ	=	accessions (scalar)
r	=	recruiting vector designating what proportion of λ are recruited into each state (dimension $1 \times k$)
I	=	Identity matrix (dimension $k \times k$)
P^T	=	Transpose of the transition matrix P (dimension $k \times k$)
k	=	number of states in the transition matrix.

3. Hypotheses

The hypotheses propose the formation of two separate matrices, one each for prior enlisted and non-prior enlisted officers. The data are generally only available to permit construction of matrices based on YOS transitions. The hypotheses are interrelated and concern the development of the optimal mix of prior and non-prior enlisted officers.

Hypothesis 1: a point exists whereby an optimal mix of prior enlisted and non-prior enlisted officers can be obtained with respect to force structure and budget constraints.

Hypothesis 2: the cost of a non-prior enlisted officer exceeds the cost of a prior-enlisted officer so that where budget is the only constraint prior enlisted officers are less costly.

Hypothesis 3: prior enlisted officers, as the only accessions, cannot provide sufficient numbers or longevity to maintain current force structure.

4. Hypothesized Effects

It is expected that there are numerical values for the optimal number of prior and non-prior enlisted USMC officer accessions. The non-existence of such values would suggest that HQMC has the flexibility to access any number of non-prior or prior enlisted officers including none at all.

The second hypothesis is thought to be true based simply on the average cost of a USNA graduate when compared to the costs of all other commissioning sources. As the majority of USMC officers from USNA are non-prior enlisted, then the contribution of the USNA officers to the average cost of non-prior enlisted officers is likely to be large in comparison to prior enlisted officers.

The final hypothesis is more ambiguous in its likely effect. The results of Chapter V indicated that prior enlisted officers appear to have a better survival rate than their non-prior enlisted counterparts. However, whether the difference is practically significant enough to suggest that non-prior enlisted officers could not maintain force structure by themselves, without changing promotion criteria or inducing bonuses, is uncertain.

D. DATA

Data for the non-parametric model were obtained from two sources, the Center for Naval Analysis (CNA) and the Defence Manpower Data Center (DMDC). In particular, two standard reports from the DMDC web site, the Officer Continuation Report and the Officer Inventory Report for 2000, were used.

1. Active Duty Officer Continuation Report

The Military Personnel Policy Active Duty Officer Continuation Report uses the DMDC active duty master files for officers (minus Coast Guard) from September 1988 through the most recent fiscal year. The purpose of the report is to show the continuation rate for officers where a ‘continuation’ is defined by matching the beginning of the fiscal year master file against the end of the year file; if a service member is present in

September 1988 and is also in September 1989 he or she is counted as a continuation for FY89.[29] This process is repeated for each year.

2. Officer End Strength Report

The Military Personnel Policy Officer End Strength Report also uses the DMDC active duty master files for officers (minus Coast Guard) and provides information on the officer end strength, by rank, continuously from 1990 to 2002.[30]

3. Marine Corps Commissioned Officer Accession Career

The MCCOAC data file from CNA, which was the same file used for development of the Cox regression model, can also be used for the non-parametric model. The MCCOAC file is described in detail in Chapter IV, and provides information regarding the careers of the prior and non-prior enlisted officers not available from other sources.

E. DATA LIMITATIONS

Data limitations for the MCCOAC file were detailed in Chapter IV Part E and still apply for the non-parametric model. The DMDC data have several limitations which can be overcome, in part, through use of the MCCOAC file. In particular, the DMDC data set cannot be clearly divided into prior and non-prior enlisted officers. As a result, estimating survival characteristics for each group is not possible with the DMDC data alone. Regardless, the DMDC data provide easy access to information on the total numbers of officers across each rank and YOS.

[29] Online source. The continuation rates are also available by gender, race and community and are displayed by service.

[30] Online source. End strengths are also available for 1980 and 1987, and also by community, race and gender.

F. DEVELOPMENT OF THE FISCAL CONSTRAINT

The fiscal constraint on the numbers of prior and non-prior enlisted officers assumes that there is an implied total budget for officer accessions. Because of the variety of methods by which accessions can occur and the number of defense agencies involved in the accession process, there appears to be no single dollar amount allocated to a single authority for officer accessions. Instead, budgets are allocated to a variety of authorities within the Department of Navy for officer accessions. Despite this, it is assumed that the combined total of the average cost of each officer accession represents a close estimate of the total budget for officer accessions.

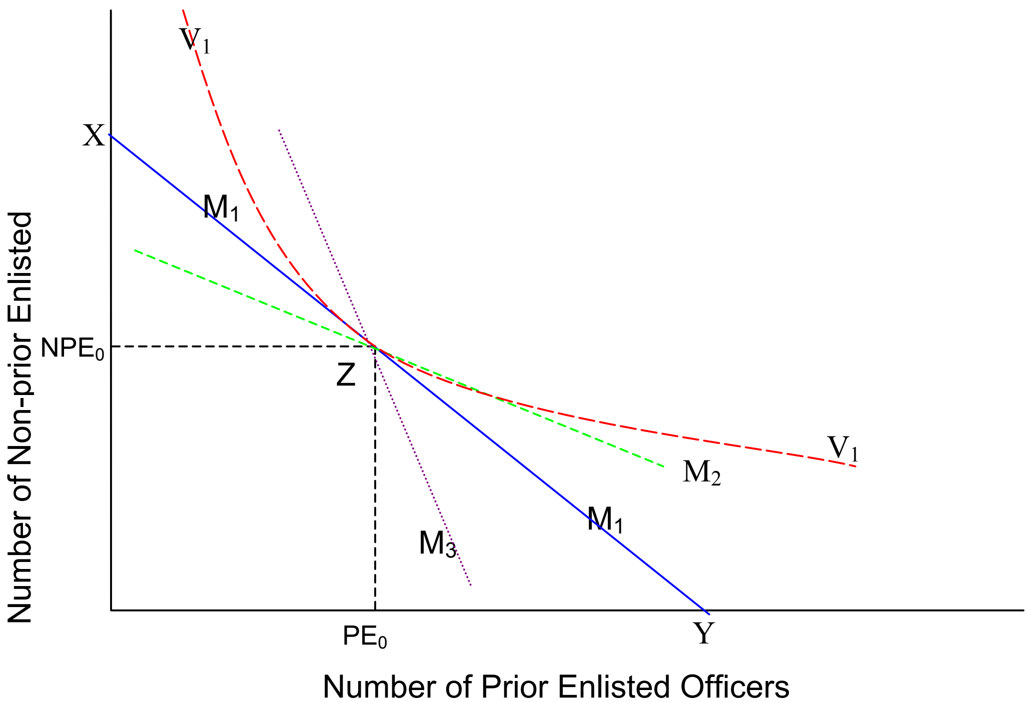
Together with the force structure constraint, described in Section G, the fiscal constraint provides one barrier which ensures the number of one type of officer, prior enlisted or non-prior enlisted, cannot exceed a certain level. To develop the fiscal constraint in isolation from the force structure constraint, it is necessary to first ignore the obvious impact of the force structure, and consider only the number of officers that can be 'purchased' given a particular budget.

1. Cost of Officers

The mix of officers, given a particular budget and without regard for the number of required officers, can be shown in Figure 3. In the diagram, the point Z is the unknown theoretical optimum mix of prior enlisted and non-prior enlisted officers, indicated by PE_0 and NPE_0 respectively. The accession budget is fixed hence prior enlisted and non-prior enlisted officers officer quantities can only change such that the total cost remains the same.

The lines represented by M_k show possible mixes of officers, holding the budget constant. Note that all lines M_k are straight suggesting that only the average costs are used to construct the diagram. If marginal costs were used, it is possible that the curve would more closely resemble V_1.

Figure 3. Potential Mixes of Prior Enlisted and Non-prior Enlisted Officers Given a Fixed Budget.



Source: Author

In any case, the line M_1 represents the special case where prior enlisted and non-prior enlisted officers are perfect substitutes with respect to cost (cost PE = cost NPE). The slope of M_1 is minus one, indicating that we can replace one prior enlisted officer with one non-prior enlisted officer on a one-to-one ratio. The points X and Y represent the theoretical situation where, using the allocated budget, all officer accessions are either prior enlisted only (Y) or non-prior enlisted only (X) and marginal costs are identical to average costs. In reality, it is doubtful that prior enlisted and non-prior enlisted officers are perfect substitutes.

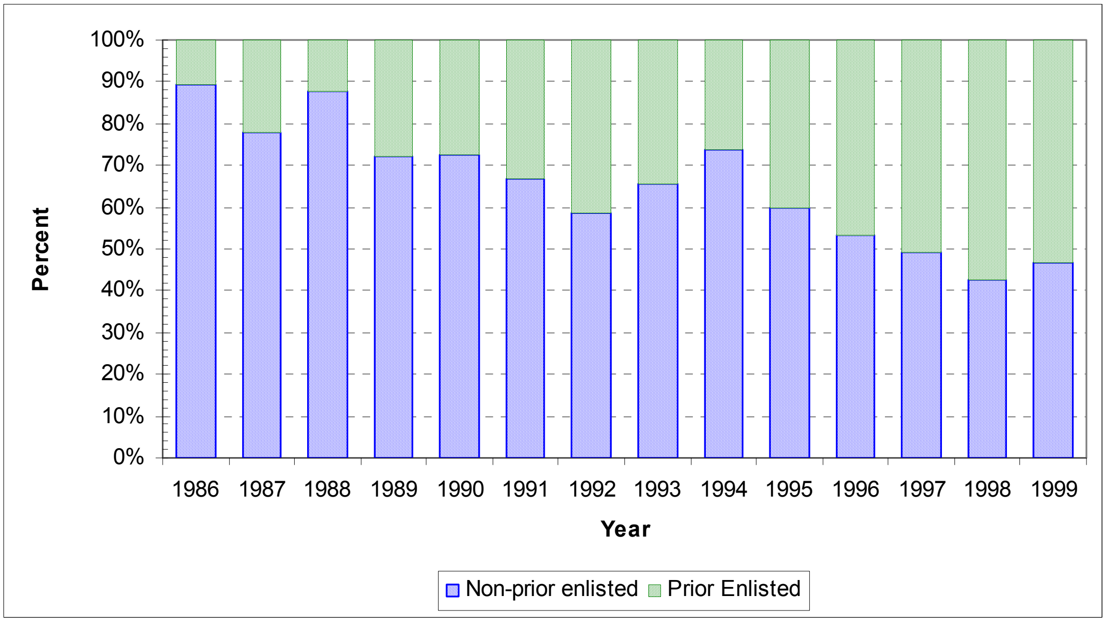
The line M_2 shows a situation where non-prior enlisted officers are more expensive than prior enlisted officers. The slope of the line is closer to zero than M_1 which means the trade-off is not one-to-one and that to increase the number of non-prior enlisted officers the number of prior enlisted officers must be decreased by more than one.

Conversely, M_3 shows the situation where prior enlisted officers are more expensive than non-prior enlisted officers. The slope is smaller than minus one which means that increasing the number of prior enlisted officers by one entails decreasing the number of non-prior enlisted officers by more than one.

The lines M_1, M_2, and M_3 all give straight-line explanations of the relationship between prior enlisted and non-prior enlisted officers, which is the case when the average costs are assumed. When marginal costs are calculated, V_1 is likely to be closer to reality indicating that the relationship between the cost of prior enlisted and non-prior enlisted officers, given a particular budget, is not constant over the range of possibilities.

Figure 4 shows, in percentage terms, the prior enlisted and non-prior enlisted officers commissioned between 1986 and 1999. At this stage, it is not possible to ascertain which line more closely reflects reality. Current data, shown in Figure 4, show the number of prior enlisted officer accessions is approaching that of non-prior enlisted officer accessions and may give the impression that M_1 is assumed by USMC officer accession planners. Of interest is the trend since 1986 which gives some suggestion that, assuming all else equal including accession budget, the USMC may be operating on M_1 where there is no apparent regard as to whether an officer was prior enlisted or not. Hypothesis 2 proposes that M_3 would better reflect reality if non-prior enlisted officers were more expensive than prior enlisted officers.

Figure 4. Observed Trend in the Proportion of Prior and Non-prior Enlisted Officers



Source: Author

2. Costs and Benefits

A general list of the costs and benefits of high levels of prior enlisted officer accessions are provided in Table 17. Many of the benefits are intangible and unquantifiable and others are problematic in their calculation. As a result, this thesis concentrates on the known costs of each commissioning source. As an example of a problematic calculation, high numbers of prior enlisted officer accessions may enable lower expenditure on officer recruiting and advertising activities; however, an ensuing increase in enlisted advertising may be required to obtain the necessary quality of enlistees to eventually become officers.

Table 17. Benefits of a High Proportion of Prior Enlisted Officer Accessions

Benefits	Costs
Increase in experience and productivity	Increased PCS cost moves
Fewer recruiters for officers	Increased recruiters for enlisted personnel
Less officer advertising	Increased enlisted personnel advertising
Increased retention of enlisted personnel	Reduced yrs of commissioned service of officers
Reduced USNA costs	Increased PLC, OCC, NROTC costs
	Increased salaries from 'ageing the force'

Source: Author

The data obtained for this thesis only enable the determination of the average cost per accession for each commissioning source, which is shown in Table 18, column (d). The cost of OCS is not included in the figures below as all officers attend OCS. Additionally, post-commissioning costs such as any necessary training and education costs required after commissioning are not included.

Table 18 shows that the average cost for ECP and MCP officers is zero. This is because officers from these commissioning sources attend OCS directly. ECP officers already posses a degree, whereas MCP officers are commissioned without a degree, and hence no costs are associated with these commissioning sources. This thesis will not include the impact of post-commissioning costs; however, it is expected that inclusion of these costs may have an effect of the optimum level of officers. Additionally, marginal costs may be more relevant for this analysis where we are considering increasing or decreasing the number of prior enlisted or non-prior enlisted officers, not completely discontinuing using particular accession sources. As stated by Bernard and Mehay "… average cost is most relevant to the decision to open or close a program, whereas marginal cost is relevant to the decision to expand or contract a program…" (Bernard and Mehay, 2003).

Table 18. Average Cost of USMC Commissioning Sources

Commissioning Source	Prior enlisted	Non-prior enlisted	Average Cost (in 2003 $)
(a)	(b)	(c)	(d)
Other[b]	21	51	-
PLC	1330	5029	$21,600
OCC	2874	1779	$21,600
NROTC	282	3269	$53,600
MECEP[a]	820	-	$53,600
ECP[c]	653	-	$0
USNA	83	1981	$229,200
MCP[d]	205	-	$0
Total (n=18464)	6265	12109	

Source: figures for MCCOAC, OCC and PLC figures from MCRC. ROTC and USNA figures from Mehay and Bernard (2003). Missing data: 90

3. The Fiscal Constraint

The fiscal constraint itself is represented by the combination of prior enlisted or non-prior enlisted officers such that the total budget for officer accessions is not exceeded. The resulting equation is a straight line showing the relationship between prior and non-prior enlisted officers:

$$\begin{matrix}\text{Cost of NPE}\\\text{officer (\$)}\end{matrix} \times \begin{matrix}\text{NPE officer}\\\text{accessions}\end{matrix} + \begin{matrix}\text{Cost of PE}\\\text{officer (\$)}\end{matrix} \times \begin{matrix}\text{PE officer}\\\text{accessions}\end{matrix} = \begin{matrix}\text{Accession}\\\text{budget}\end{matrix} \qquad (8)$$

a [a]ECP and MCP have no attributed costs because these personnel enter OCS directly without residential attendance on a commissioning course such as PLC, OCC, NROTC or USNA. MECEP costs are estimated as the same as NROTC as MECEP accessions are required to undertake a degree through NROTC. OCS and TBS costs are not included as these costs are approximately the same for each commissioning source except USNA graduates who do not attend OCS.

b Average cost of 'other' assumed to be $0.

c ECP officers already possess a degree, hence they are not required to undertake a program such as NROTC. These officers attend OCS/TBS directly.

d MCP officers do not have a degree on commissioning however are expected to pursue one after commissioning. MCP officers may have otherwise higher post-commissioning costs which are not captured in the above table.

G. DEVELOPMENT OF THE FORCE STRUCTURE CONSTRAINT

The force structure constraint assumes that there is a particular number of officers, at each rank, that cannot be exceeded. Together with the fiscal constraint described in Section F, the force structure constraint provides a second barrier that ensures that the combined number of prior enlisted or non-prior enlisted officers, cannot exceed a certain number. To develop the force structure constraint in isolation from the fiscal constraint, it is necessary to consider only the number of officer accessions required to maintain a particular force structure, without regard for their respective costs.

Specification of the constraint on the mix of prior enlisted or non-prior enlisted officers in terms of force structure required the use of both the MCCOAC data file and standard reports available on the DMDC web site. The method used involves determining what mixes of officers would provide suitable quantities to maintain the officer force structure, that is, the mix of prior enlisted and non-prior enlisted officers required at the O-1 level to provide suitable numbers of O-4's.

1. Assumptions

There are three critical assumptions in predicting force structure that simplify reality. The first is that selection criteria for promotion have not changed since 1986 and are not likely to change in the future. This assumption is necessary because, in reality, any shortage in ranks above O-4 could easily be controlled by relaxing promotion criteria (and vise versa). This paper requires selection criteria to remain constant such that, on average, the promotion pattern of officers in 2000 is the same as the promotion pattern from 1986 onwards.

The second simplifying assumption is that all officers follow the same career pattern in terms of years spent at each rank. The assumption is that all officers, both prior enlisted or non-prior enlisted, spend two years as an O-1, two years as an O-2, six years as an O-3, and five years as an O-4. There is insufficient data to consider careers beyond O-4. This assumption only approximates reality, as prior enlisted officers can, and often do, enter with several years of seniority or even a rank seniority depending on specialty;

and all officers can be promoted early, late, or even demoted. For the purpose of the model, restated below, all officers are 'recruited' into O-1 and at year one.[31]

$$s(t) = \lambda(I - P^T)^{-1} r$$

The final simplifying assumption is that the loss patterns for officers have been generally the same since 1986.[32] This again does not reflect reality as there are many external factors affecting retention including the state of the economy, and downsizing, to name just two. This assumption simplifies analysis as it permits the creation of an estimated 'steady state' force structure.

The combined effects of the assumptions on the model is that the transition matrix P remains constant, r is a vector of (1,0,0,0,…,0) and therefore λ, the number of accessions, can be varied to maintain the force structure.

2. Transition Matrices

DMDC has provided a routine report on the continuation rates of officers by years of service continuously since 1990. This matrix, as detailed earlier, defines a 'continuation' as a service member who was present in year t and in year $t+1$. The resulting percentages indicate all those personnel who had remained since the previous year. Unfortunately, the data do not permit separation into prior enlisted or non-prior enlisted officers so it is necessary to use the MCCOAC file detailed in Chapter IV.

The MCCOAC data file provides sufficient information to determine the historical separation rates for prior enlisted and non-prior enlisted officers, by FY cohort since 1986. It is possible, from this information, to develop a Years of Service (YOS) non-parametric transition model that indicates the probabilities of transition of an individual from one YOS to the next for each cohort from 1986 to 1999, for both prior and non-prior enlisted officers.

---

31 In the context of equation 7, this assumes the recruiting vector r consists of (1,0,0,0,….,0) so that all accessions enter the transition matrix at YOS =1.

32 In the context of equation 7, this assumes that a steady state exists and is meaningful.

The data are severely limited for development of the transition matrices owing to the cohorts available for analysis. For example, the 1986 cohort data provide sufficient information to develop a transition matrix for 14 years (or typically to the end of O-4). Later cohorts, such as 1999, have only one year of data to determine transition probabilities. Therefore, between 1986 and 1999 there are 14 estimates for the transition from YOS 1 to YOS 2, but there is only one estimate (from the 1986 cohort) for the transition from YOS 14 to YOS 15. To construct a complete transition matrix, it is assumed in the absence of additional information, that the survival probabilities in the earlier years represented by the data provide an adequate estimate of successive survival probabilities where the information is not available.

3. Force Structure Constraint

When the separate transition matrices for prior and non-prior enlisted officers are used together, it is possible to determine how many officers would exist, in a steady state, if particular accession figures for prior and non-prior enlisted officers were used. For example, if 3000 O-4's were required in steady state, it is possible to determine all combinations of prior and non-prior enlisted officer accessions that would result in 3000 O-4's. In other words, the force structure constraint is the combination of prior and non-prior enlisted officer accessions such that the number of officers required at a particular rank is obtained. The steady-state transition matrices are valuable as they allow the officer accession numbers for both prior and non-prior enlisted officers to be varied while keeping the officers required at a particular rank constant. The simple linear form of this constraint is:

$$\delta_1 \times \begin{array}{c}\text{NPE officer}\\ \text{accessions}\end{array} + \delta_2 \times \begin{array}{c}\text{PE officer}\\ \text{accessions}\end{array} = \begin{array}{c}\text{Officers required at a}\\ \text{particular rank}\end{array} \qquad (9)$$

where δ_1 and δ_2 are coefficients which determine the slope of the force structure constraint resulting from the possible combinations of officers accessions required to obtain the prescribed number of O-4 officers. The coefficients can be easily obtained by setting one group of officers equal to zero, and determining the number of the remaining group of officers necessary to obtain the prescribed number of officers at a particular rank.

H. CHAPTER SUMMARY

As detailed in the overview of this chapter, the methods used to obtain the optimum mix of officers, including the steady state transition matrix and the constraints, all make several simplifying assumptions that generalize the resulting model. For the fiscal constraint the assumptions include the requirements that the linear form of the constraint be approximately straight around the optimal value and that a value for the accession budget can be estimated. The force structure constraint makes the assumptions that selection criteria for promotion are constant, the number of years spent in each rank is the same for all officers, and that loss rates have been constant since 1986 and will continue at that level.

The two constraints discussed in this chapter can, in theory, be applied to the APD in an attempt at determining their intersection if one exists. The intersection represents that point where the number of prior and non-prior enlisted officer accessions provide for the requirements of the force structure and within the allocated accession budget.

VII. MARKOV OPTIMIZATION OF ACCESSIONS

A. PRELIMINARY ANALYSIS

Although the theory behind each constraint can be difficult to explain, the application of theory in determining the algebraic form of the constraints is not particularly complex. The application of each constraint in determining the optimum, is also simpler than the explanation of the methodology. This chapter expands on the theory from Chapter VI to determine the algebraic form of the constraints and the subsequent optimum.

The methodology discussed in Chapter VI was designed to determine the optimum number of prior and non-prior enlisted officer accessions across the entire USMC. The method can also be considered for optimizing accession numbers within an occupation and within a commissioning source. The second half of this chapter discusses the use of the optimization approach when the data are separated into occupational groups and commissioning sources.

1. Fiscal Constraint

Equation (8) shown in Section F of Chapter VI specified the fiscal constraint. It is possible, using the average costs already presented, to determine the constant values in equation (8). Using the figures listed in Table Table 18. and omitting the 'other' category, the remaining 6,265 prior enlisted officers (including those from MECEP, ECP and MCP) had an average cost of approximately \$27,036 in 2003 dollars. The 12,109 non-prior enlisted officers had an average cost of approximately \$64,382 in 2003 dollars.[33]

Overall, the average cost per accession is \$51,637. Since the average number of officer accessions since 1986 has been 1319 officers (449 prior enlisted and 870 non-prior enlisted), this implies that the average 'budget' for officer accessions is approximately \$68,150,420 (in 2003 dollars). This figure represents the fiscal constraint in that the total cost of officer accessions should not exceed \$68,150,420. Substituting the

[33] It is worth noting that the average cost per prior enlisted and non-prior enlisted officer presented here is aggregated across commissioning sources and has no individual level meaning.

values obtained for the accession costs and total costs into equation (7), the straight-line equation for this constraint is approximated by:

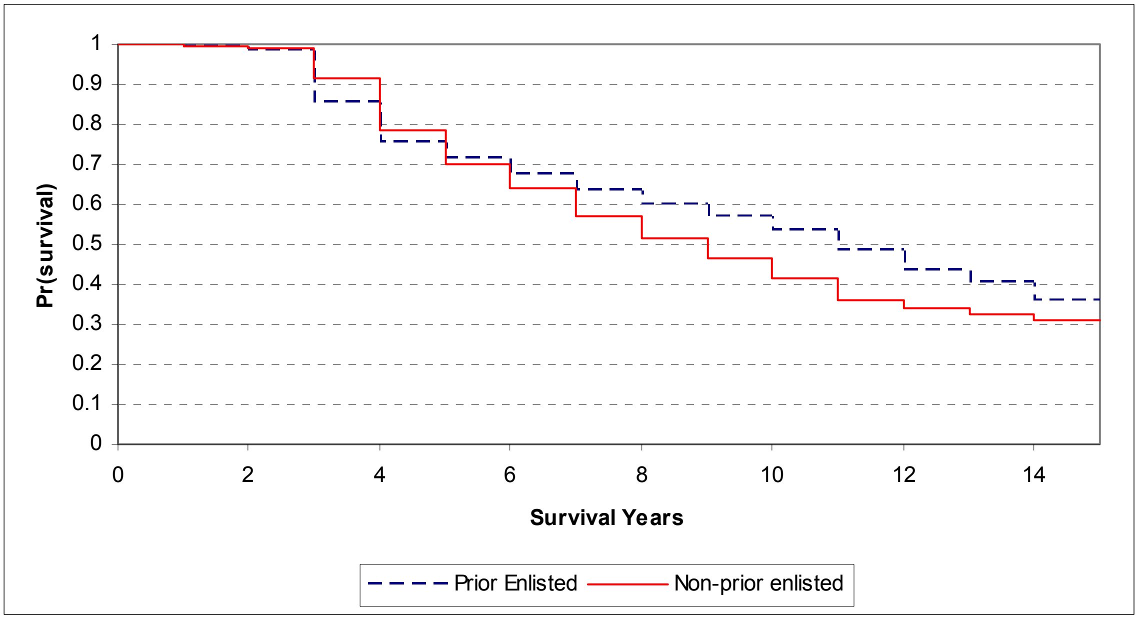
$$\$64{,}382 \times \text{NPE} + \$27{,}036 \times \text{PE} = \$68{,}150{,}420 \text{ (budget)} \qquad (10)$$

2. Force Structure Constraint

By developing the transition matrices described in Section G of Chapter VI, it is possible to determine the constants δ_1 and δ_2 shown in equation (9). Because it is not expected that the survival rates for prior and non-prior enlisted officers are the same, δ_1 and δ_2 are also not expected to be the same.

Figure 5 shows the survival rates for prior enlisted and non-prior enlisted officers from commissioning onwards using Kaplan-Meier (KM) estimates and gives an indication of the difference in the survival rates between the two groups. The diagram appears as stepwise because the data do not permit for accurate calculation of survival within a year; hence separations are all assumed to take place at the end of the year. Additionally, as expected, for the first three transitions the survival rate is close to one which reflects the restriction on separations until completion of an initial obligation period. The remainder of the diagram shows a gradual difference in the separation rates with prior enlisted officers showing a greater propensity for survival. The transition matrices derived from the KM estimates for prior and non-prior enlisted officers are shown in appendices A and B respectively.

Figure 5. Stepwise Survival Rates for Prior and Non-prior Enlisted Officers



Source: Author.

The predetermined number of officers required at any particular rank (left-hand side of equation (9)) can be varied according to information known to planners. Indeed one benefit of the model used for non-parametric optimization is the flexibility in determining the number of officers required at any rank. The KM estimates, however are determined from historical survival rates; hence the constants δ_1 and δ_2 should not be varied.[34]

The values chosen for the number of officers required at a given rank for the remainder of this thesis are based on the historical average of O-4's from 1995 to 1999 inclusive, or 3,280 officers. A sensitivity analysis will use other values which may be chosen to optimize the number of officer accessions.

The constants δ_1 and δ_2 are determined by initially setting either prior or non-prior enlisted officer accessions in equation (9) to zero. Using the transition matrix for the remaining type of officer it is then possible to determine the number of accessions required for that officer type to obtain a predetermined number of officers at a certain

[34] As further cohort data becomes available the KM estimates should be revised and adjustments to constants made accordingly.

rank, say O-4. Determining the coefficient is then just a simple algebraic solution. The same process is repeated for the remaining officer type. For example:

Step 1. Set one group of officers to zero and determine the number of officers required at O-4:

$$\delta_1 \times \begin{array}{c}\text{NPE officer}\\ \text{accessions}\end{array} + \delta_2 \times \begin{array}{c}\text{PE officer}\\ \text{accessions}\end{array} = \begin{array}{c}\text{Officers required at a}\\ \text{particular rank}\end{array} \tag{11}$$

$$\Rightarrow \quad \delta_1 \times 0 + \delta_2 \times \begin{array}{c}\text{PE officer}\\ \text{accessions}\end{array} = 3{,}280$$

Step 2. using the transition matrix for prior-enlisted officers, determine the number of accessions required to obtain 3280 O-4's in the steady state.

$$\Rightarrow \quad \delta_2 \times 1115 = 3{,}280$$

Step 3. Solving for δ_2: $\delta_2 = 2.94$.

Step 4. Repeat the above steps setting the number of prior enlisted officers to zero.

The final result of the force structure constraint, which is assumed to be a straight line near the optimum, can be applied to equation (9) and is approximated by:[35]

$$2.627 \times \text{NPE} + 2.941 \times \text{PE} = 3{,}280 \text{ (O-4's)} \tag{12}$$

[35] In the case of the 95-99 average force structure the number of O-4's was 3280 on average.

B. ACCESSION OPTIMIZATION FOR ALL COMMISSIONING SOURCES

1. Optimization Results

The intersection of the two constraint lines (equations (10) and (12)) indicates the point at which a force structure necessary to obtain 3,280 O-4's can be achieved within the assigned budget. Note that it is possible within the construct of this model to obtain a force structure with 3,280 O-4's for less than the assigned budget; however, this was not the goal.

Solving for prior and non-prior enlisted officer accessions gives the optimum number as:

Optimum prior enlisted officer accessions	=	272	(22.4%)
Optimum non-prior enlisted officers accessions	=	944	(77.6%)
Total officers	=	1216	(100%)

The total value is just 49 officers below the estimated requirement of 1,265 for 2003 and just 11 officers above the 2003-2006 average of 1,205 provided by HQMC. The mix however, is different from recent trends which indicate the actual ratio of prior to non-prior enlisted officer accessions is closer to 1:1 (see Figure 4.).

2. Sensitivity Analysis

There are two ways to conduct a sensitivity analysis of the results. The first is to use a 95 percent confidence interval of the KM estimates and apply this to the force structure constraint. The second is to conclude that the figures used in calculating the fiscal constraint may not be entirely correct, and the figure used for the number of O-4's required may not be correct.

Using the second method, sensitivity regions can be determined for each of the constraints. In reality, the fiscal constraint may vary from that calculated earlier in this thesis by plus or minus ten percent; and the force structure constraint may be better calculated by using the average number of O-4's from 1990-1999 or just the raw number in the most recent year, 1999, rather than the average over 1995-1999. By changing the figures used for the force structure constraint it is possible to obtain upper and lower limits for the force constraint using the following two equations:

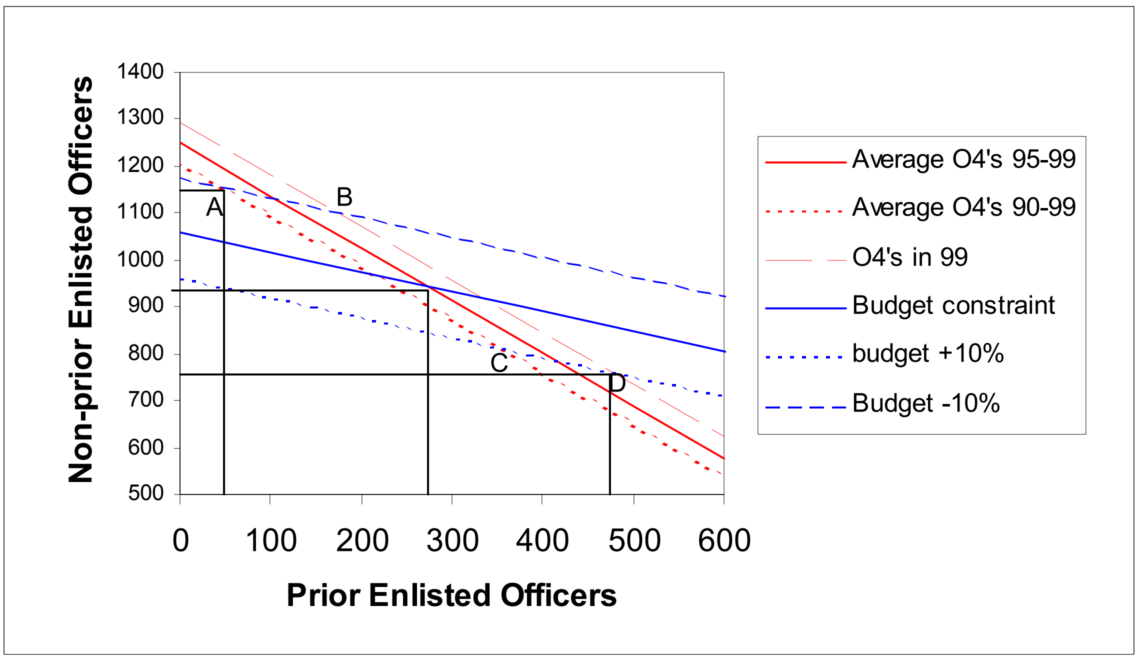
$2.627 \times NPE + 2.941 \times PE = 3{,}400$ (number of O-4's in 1999 only)

$2.627 \times NPE + 2.941 \times PE = 3{,}180$ (average number of O-4's from 1990-1999)

Note that the constants have remained the same. This occurs because the transition matrices, which determine the constants, have remained unchanged.

Figure 6 shows the application of the above two equations and a ten percent margin of error on the individual calculations of the average cost of each commissioning source (the total fiscal constraint of approximately $68 million remains constant). The result is the region ABDC showing the optimization results as a range of values for prior and non-prior enlisted officer accessions.

Figure 6. Sensitivity Diagram for the Optimization of Prior and Non-prior Enlisted Officer Accessions



Source: Author.

The table below indicates the coordinates for the corners of the resulting region of possible optimum solutions with the center point (optimum) located at coordinates (272, 944).

Table 19. **Optimization Sensitivity Results**

Point	PE	NPE	TOTAL
A	48	1156	1204
B	169	1105	1274
C	354	814	1168
D	475	763	1238
Optimum	272	944	1216

Source: Author. All figures have been rounded to the nearest integer.

3. Summary of Optimization for All Commissioning Sources

Using the sensitivity analysis and equations (10) and (11), the optimal values for prior enlisted and non-prior enlisted officer accessions is estimated to be approximately 272 and 944, respectively. As indicated in Table 19, the value for prior enlisted could vary from approximately 48 to 475 and non-prior enlisted could vary from 763 to 1,156 within the boundaries indicated in Figure 6.

As noted previously, the relationship between prior and non-prior enlisted officer accessions is assumed to be a straight line around the optimum. However, it is likely that the farther from the optimum the less likely the relationship will remain linear as described in the earlier equations and figures. This thesis does not assume that equations (10) and (12) can be extrapolated toward the axis for a meaningful result because it is suspected that the relationship does not maintain a straight line. This is likely to be true where marginal costs are used rather than average costs.

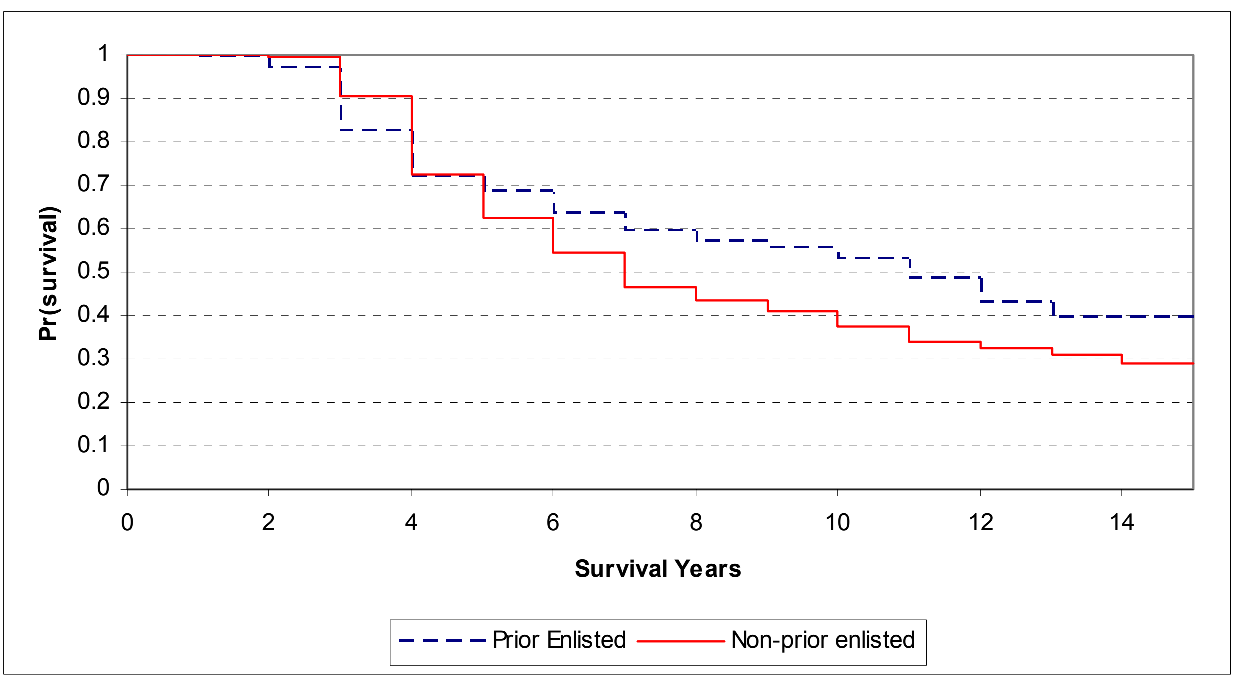
C. ACCESSION OPTIMIZATION BY OCCUPATION

Using the same methodology, it is also possible to optimize accessions within the three general occupational fields. In order to achieve this it is necessary to know the requirement for officers within each occupational field at the O-4 rank. DMDC data indicates that there were 3,280 O-4's from 1995-1999 and the MCCOAC data indicates that 28.65 percent were in combat-related occupations, 46.70 percent in combat support-related occupations, and 24.65 percent were in combat service support-related occupations in 1999. Using the MCCOAC percentages, of the 3,280 O-4's, 940 were in combat, 1,532 were in combat support, and 809 in combat service support. These figures represent the 'goals' for each of the three optimizations.

1. Optimization for Combat Officers

Figure 7 shows the survival diagram based on KM estimates for prior and non-prior enlisted officers in combat-related occupations. As with the overall optimization, Figure 7 provides evidence of a difference between the officer types.

Figure 7. Survival Rates for Prior and Non-prior Enlisted Officers in Combat-Related Occupations



Source: Author

The implied accession budget for combat-related officers is \$20,833,519 and the constants in fiscal constraint remain the same, hence the fiscal constraint is given by:

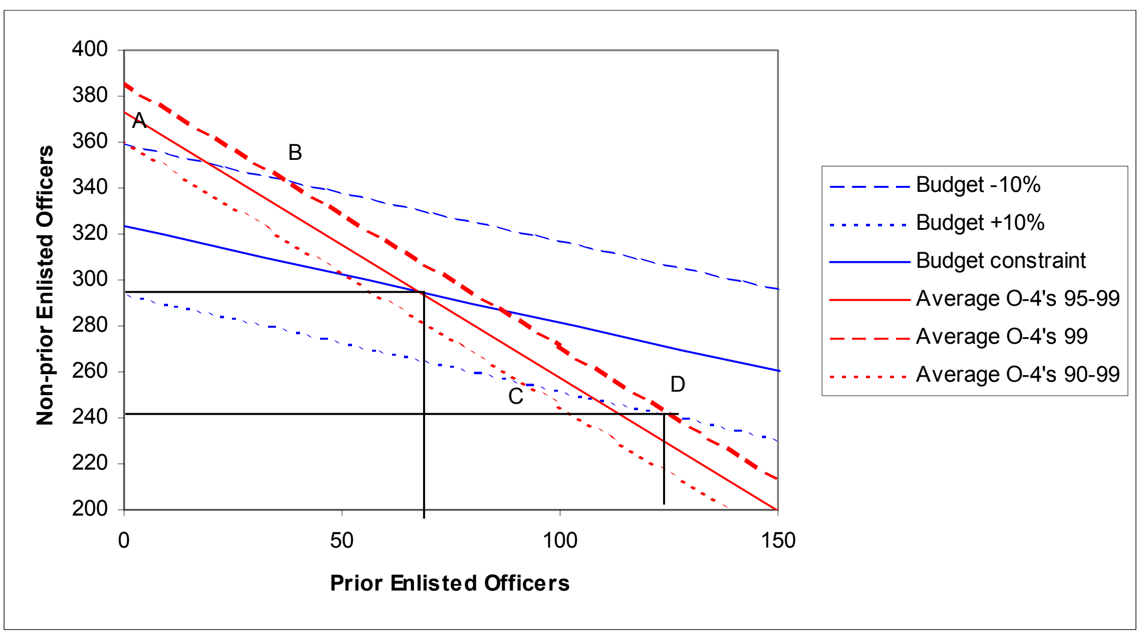
$$\$64,382 \times \text{NPE} + \$27,036 \times \text{PE} = \$20,833,519 \text{ (budget)} \qquad (13)$$

The force structure constraint is determined in the same manner as the overall optimum. The constants have changed very little when compared with equation (12) indicating the similarity in the relationship between the combat occupations and the overall occupations.

$$2.521 \times \text{NPE} + 2.910 \times \text{PE} = 940 \text{ (O-4 combat officers)} \qquad (14)$$

The resulting optimum, shown diagrammatically in Figure 8, is 295 non-prior enlisted officers and 67 prior enlisted officers. Table 20 shows the sensitivity analysis using the same sensitivity criteria as detailed earlier. The number of prior enlisted officers, according to the sensitivity analysis, is between two and 126 while the range for non-prior enlisted officers is 241 to 359.

Figure 8. Sensitivity Diagram for the Optimization of Combat-Related Prior and Non-prior Enlisted Officer Accessions



Source: Author.

Table 20. Optimization Sensitivity Results for Combat Occupations

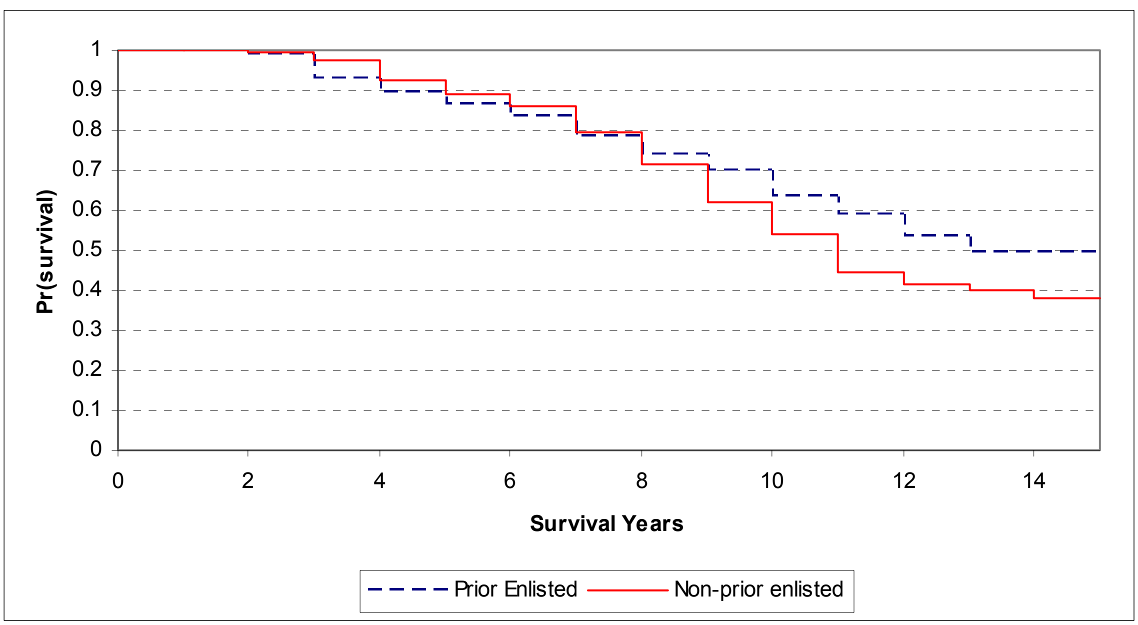
Point	PE	NPE	TOTAL
A	2	359	361
B	37	344	381
C	91	256	347
D	126	241	367
Optimum	67	295	362

Source: Author.

2. Optimization for Combat Support Officers

Figure 9 shows the survival diagram for prior and non-prior enlisted officers in combat support-related occupations. Unlike the combat officers, the difference is less obvious and is only noticeable from nine YCS. Again, there is visual evidence of a difference between prior and non-prior enlisted officers in terms of their survival rates.

Figure 9. Survival Rates for Prior and Non-prior Enlisted Officers in Combat Support-Related Occupations



Source: Author.

The implied accession budget for combat support officers is \$26,223,044 and as with previous optimizations, the constants in the fiscal constraint remain the same. Hence the fiscal constraint is given by:

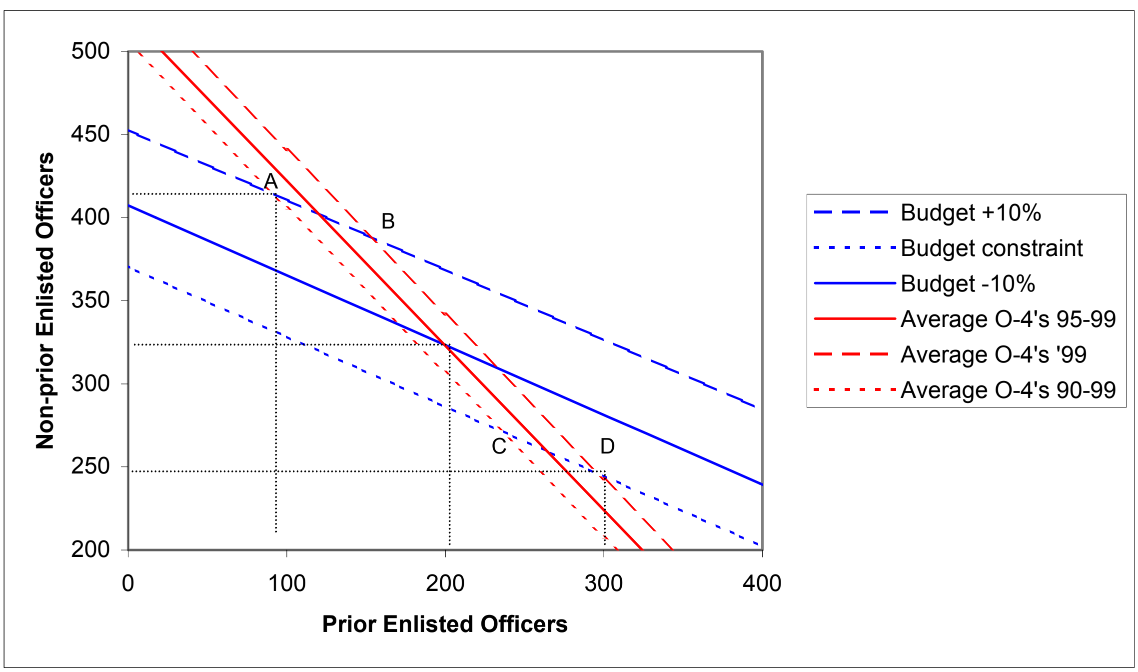
$$\$64{,}382 \times \text{NPE} + \$27{,}036 \times \text{PE} = \$26{,}223{,}044 \ \text{(budget)} \qquad (15)$$

The constants, δ_1 and δ_2, in the force structure constraint are very similar (0.027 differences) implying that, in terms of the survival rate, prior and non-prior enlisted officers are close to perfect substitutes.

$$2.939 \times \text{NPE} + 2.912 \times \text{PE} = 1532 \ \text{(O-4 combat support officers)} \qquad (16)$$

The resulting optimum, shown diagrammatically in Figure 10, is 323 non-prior enlisted officers and 200 prior enlisted officers. Table 21 shows the sensitivity analysis using the same sensitivity criteria as detailed earlier. The number of prior enlisted officers, according to the sensitivity analysis, is between 92 and 297 while the range for non-prior enlisted officers is 245 to 414.

Figure 10. Sensitivity Diagram for the Optimization of Combat Support-Related Prior and Non-prior Enlisted Officer Accessions



Source: Author.

Table 21. Optimization Sensitivity Results for Combat Support Occupations

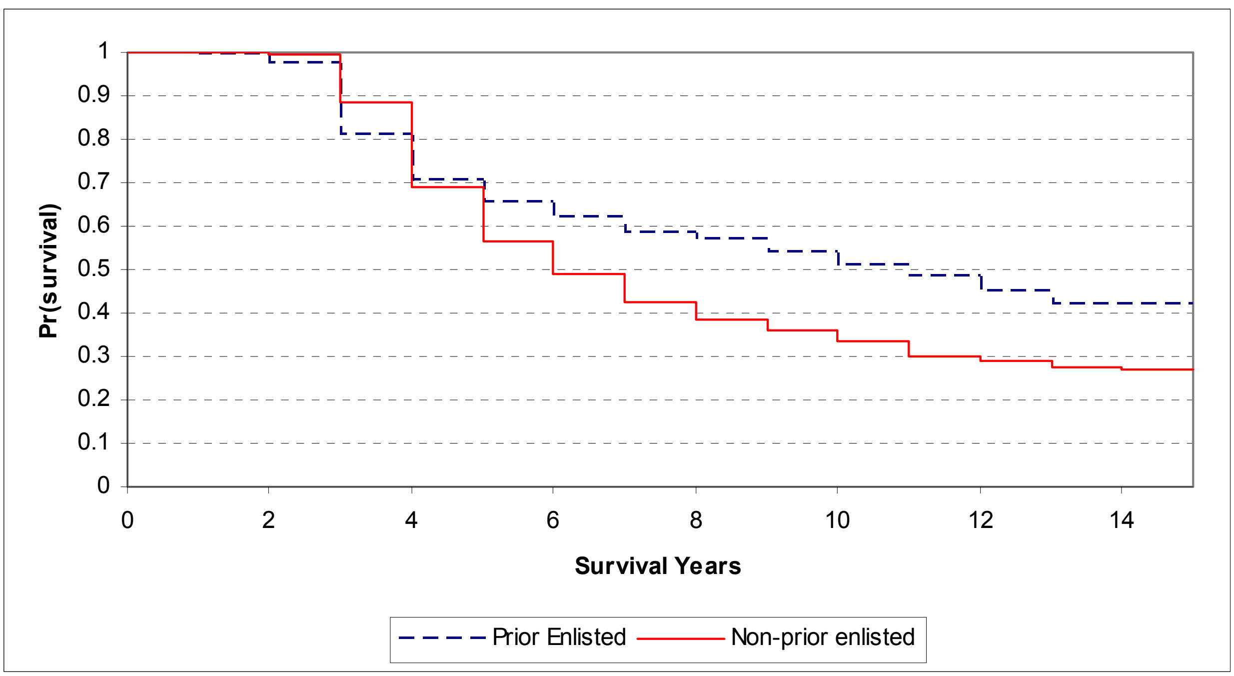
Point	PE	NPE	TOTAL
A	92	414	506
B	153	388	541
C	236	271	507
D	297	245	543
Optimum	200	323	523

Source: Author.

3. Optimization for Combat Service Support Officers

Figure 11 shows the survival diagram for prior and non-prior enlisted officers in combat service support-related occupations. The survival curves are not unlike those exhibited by the combat officers.

Figure 11. Survival Rates for Prior and Non-prior Enlisted Officers in Combat Service Support-Related Occupations



Source: Author.

The implied accession budget for combat support officers is \$21,110,293 and as with previous optimizations, the constants in the fiscal constraint remain the same. Hence the fiscal constraint is given by:

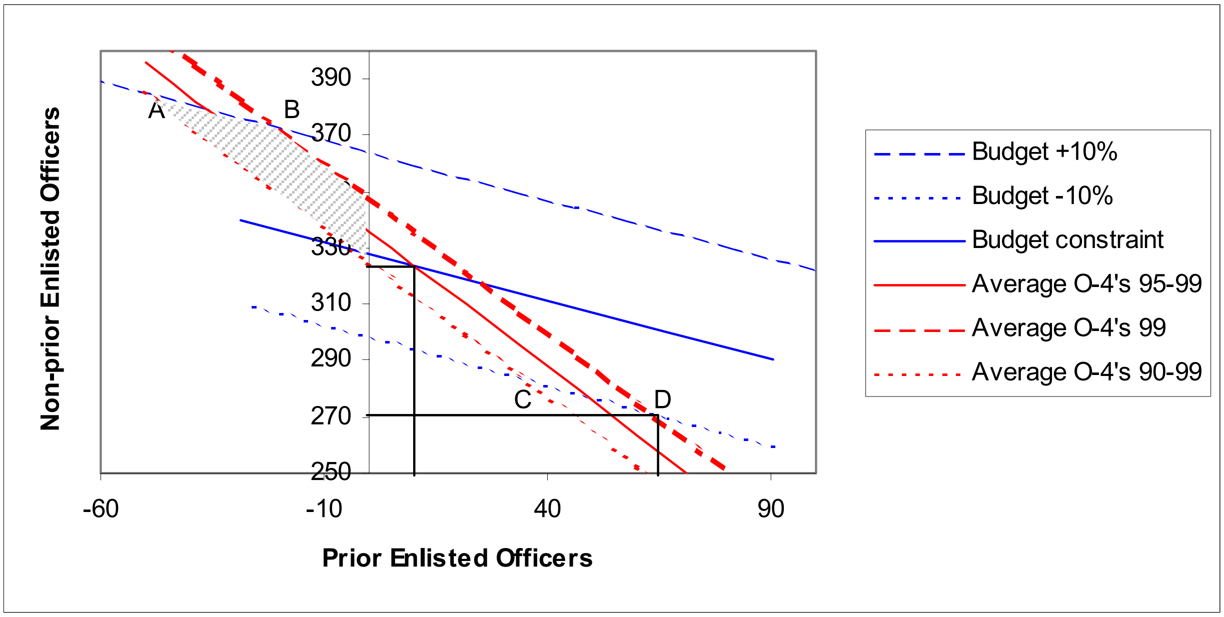
$$\$64{,}382 \times \text{NPE} + \$27{,}036 \times \text{PE} = \$21{,}110{,}293 \text{ (budget)} \tag{17}$$

The differences between the constants, δ_1 and δ_2, in the force structure constraints is somewhat larger than those for combat and combat support officers. This relatively large difference implies that the behavior of prior and non-prior enlisted combat service support officers is considerably different from members of the other two groups. Furthermore, the relatively large coefficient for prior enlisted officers is likely to reduce the optimal number of prior enlisted combat service support officer accessions.

$$2.409 \times \text{NPE} + 3.574 \times \text{PE} = 809 \text{ (O-4 combat support officers)} \tag{18}$$

The resulting optimum, shown in Figure 12, is 324 non-prior enlisted officers and 10 prior enlisted officers. Table 22 shows the sensitivity analysis using the same sensitivity criteria as detailed earlier. The sensitivity analysis for the CSS officers provides two points, A and B, which are not feasible owing to the negative numbers, and an area in the sensitivity region to the right of zero prior enlisted officers where the solutions are also unrealistic, represented by the shaded area. In this optimization, only the results to the right of zero prior enlisted officers can be considered realistic. The optimization results suggest that prior enlisted officer accession figures should be kept to a relatively small number for CSS officers.

Figure 12. Sensitivity Diagram for the Optimization of Combat Service Support-Related Prior and Non-prior Enlisted Officer Accessions



Source: Author.

Table 22. Optimization Sensitivity Results for Combat Service Support Occupations

Point	PE	NPE	TOTAL
A	-50	385	-
B	-21	373	-
C	35	283	318
D	63	271	334
Optimum	10	324	334

Source: Author.

4. Summary of Optimization by Occupation

When the optimum results for each occupation are summed together, the result is very close to the overall result detailed in Section B, including the sensitivity analyses. This is not particularly surprising as the occupation optimizations arise from the disaggregation of the data used in the overall optimization.

Table 23. Optimization Summary by Occupation

Occupation	PE	NPE	TOTAL
Combat	67	295	362
Combat Support	200	323	523
Combat Service Support	10	324	334
Total	277	942	1219

Source: Author.

The optimizations for each occupation show that although an overall result can be obtained, the ratio of prior enlisted to non-prior enlisted cannot be generalized across each occupation. This is also likely to be true if the data were further divided by MOS. However, because the KM estimates require significant amounts of data, the sample could not be separated into MOS groups while maintaining integrity in the KM estimates.

Regardless, the optimizations give an indication that the values for prior and non-prior enlisted officers vary significantly across occupations. In terms of the two constraints, there is evidence to suggest that prior enlisted officers may not benefit CSS-related occupations when compared with combat and CS occupations. However, significant numbers of prior enlisted officers in the combat and CS-related occupations are useful in maintaining the force structure within the assigned budget.

D. ACCESSION OPTIMIZATION BY COMMISSIONING SOURCE

Ideally, an additional subdivision of the optimization problem by commissioning source, may also be useful. However, at least three serious problems can be encountered when attempting this optimization.

As discussed previously, in order to optimize the number of prior and non-prior enlisted officers it is necessary to know what the 'goal' is. Commissioning source is not considered a criterion for promotion and, as a result, there exists no quota of O-4's which must come from any given commissioning source. This means there is no goal for a particular number of officers at any given rank from any given commissioning source. It is possible to make assumptions based on how many of the O-4's in 1999 originated from a particular commissioning source; however, the results probably cannot be generalized for a particular commissioning source across several cohorts.

An additional problem arises when the slopes of the two constraints are not sufficiently different to permit the determination of an optimum value. The average costs for prior and non-prior enlisted officers within each commissioning source are the same, hence the slope of the fiscal constraint on the APD is exactly negative one. Furthermore, if the survival rates for prior and non-prior enlisted officers within a commissioning source are not sufficiently different, then δ_1 and δ_2 will be very similar and the result will be two lines that are almost parallel. Even if the two constraint lines eventually intersected, any sensitivity analysis would result in a large range of possible solutions.

A final problem occurs when, in dividing the sample by commissioning source, the resulting sample size is reduced to levels where the KM estimates are not reliable. The overall optimization discussed in Sections A and B, and the optimization by occupations discussed in Section C, benefit from aggregation. However, some commissioning sources are too small in their own right to enable particularly robust KM estimates, and therefore the force structure constraints may not be accurate.

Nevertheless, for those commissioning sources with participation from both prior and non-prior enlisted officers, it is possible to conduct the same calculations and obtain an 'optimization' of sorts. PLC and OCC are the only commissioning sources that provide a suitable number of both prior and non-prior enlisted officers to allow reasonable KM estimates. As the calculations follow exactly the method used so far, and some of the problems discussed above are encountered, only an optimization for PLC is discussed.

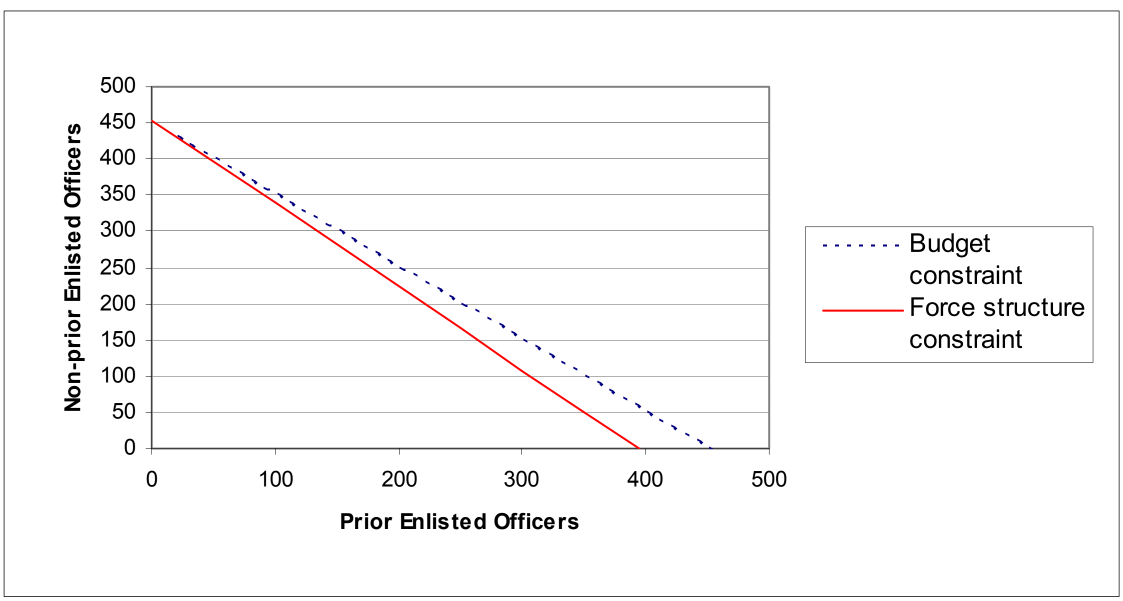
1. Example of an Optimization by Commissioning Source

In 1999, 35.43 percent of currently serving O-4 officers were commissioned through PLC. If the total number of O-4's required is 3,280, then it follows that 1162 O-4's should originate from PLC. This figure can be used to establish the force structure constraint as was done previously. Calculation of the constants provides the following equation.

$$2.558 \times \text{NPE} + 2.944 \times \text{PE} = 809 \text{ (O-4 officers from PLC in 1999)} \qquad (19)$$

The fiscal constraint is dependent only on the implied accession budget for PLC. There are, on average, 454 accessions through PLC, at an average cost in 2003 dollars of $21,600, for a total implied accession budget of approximately $9.8 million. In the economic sense, the two types of officers are perfect substitutes and the slope of the fiscal constraint is exactly negative one and must pass through 454 on both the prior and non-prior enlisted axis.

Figure 13. Optimization of Officer Accessions Through PLC



Source: Author.

The result, shown diagrammatically in Figure 13, illustrates the problem caused when the difference in the slopes is not great enough to obtain a meaningful optimal solution. Creation of a sensitivity region as was done in earlier section would result in a very large area which would consequently give almost useless results. Furthermore, the intercept implies that all accessions through this particular commissioning source should be non-prior enlisted, a solution which does not make much practical sense.

One method that may be used to determine a solution and minimize some of the problems is to differentiate further between the costs of prior and non-prior enlisted officers from the same commissioning source. This is not possible using average costs; however, it can be done using either marginal costs or a costs/benefits analysis similar to that detailed earlier in Table 17.

E. CHAPTER SUMMARY

By using the constraints on accession numbers presented by the force structure, as defined by the number of O-4 officers required at steady state, and the budget as calculated by the average cost of commissioning sources, it is possible to determine optimum results for the numbers of prior and non-prior enlisted USMC officer accessions. Overall, the optimum number of prior and non-prior enlisted officer accessions is 272 and 944 accessions respectively.

The model can also be used to optimize across occupational categories. It was found that prior enlisted officers in combat support-related occupations should contribute more toward maintaining the force structure than they do in combat service support-related occupations. In combat service support occupations, the calculations indicate that very few prior enlisted officers are required to maintain the force structure.

Unfortunately, the model is not suitable for optimization where the linear form of one constraint is similar to the linear form of the other, such that the constraints are almost parallel. In this situation the calculation of optimal figures may be subject to increased margins of error. Additionally, when the amount of data used to determine the KM estimates becomes small, as occurs during disaggregation of the data, the model is also subject to error.

There are also several conditions on the constraints which have already been highlighted several times. Firstly, the constraints cannot be extrapolated toward both axes as the relationship between prior and non-prior enlisted officers is most likely not linear over the entire range of possibilities. Secondly, the assumption of a straight line for the budget constraint is a simplifying assumption resulting from the lack of information necessary to develop marginal costs.

THIS PAGE INTENTIONALLY LEFT BLANK

VIII. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY OF RESULTS

The results obtained from the semi-parametric Cox regression and the non-parametric optimization can provide decision makers with the quantitative information necessary to assist with decisions in regard to accession numbers. This chapter summarizes the results of the models used in this thesis and provides recommendations and topics for further study.

1. Semi-parametric Model Results Summary

The Cox Regression Method identified those characteristics of officers that affect their survival rates relative to a base case. It was found that prior enlisted officers had a slightly better survival rate, experiencing 93.8 percent of the hazard of non-prior enlisted officers. This result indicates that, with all other factors being equal, prior enlisted officers will leave the USMC at a slower rate than their non-prior enlisted counterparts.

Other significant results showed that only officers from MECEP had a lower hazard than USNA, whereas PLC, OCC, NROTC and ECP all had decreased survival rates in comparison to USNA. Commissioning age was found to have a small but significant effect on survival with the hazard decreasing by 3.34 percent for every additional year of age at commissioning. Additionally, marital status had a large significant effect on survival; married officers experienced a hazard just 41.2 percent of that of non-married officers.

The effects of age and marital status reflect the economic theory of the labor market. The positive effect due to age may be attributed to the increased possibility of a successful job match as an individual grows older. In other words, the older an individual gets the more likely he or she is to know what he or she wishes to do. The positive effect of marital status is reflected in all reviewed military and civilian literature and is likely a result of the desire of a married individual for financial stability.

The officer’s occupation was also found to yield a significant and unexpected result. Officers in both combat and combat service support-related occupations were found to have a very high hazard of 176 and 200 percent respectively compared with combat support-related officers. The reasons for the different hazard rates are uncertain and should be subject to further research. It is possible that combat service support skills are more readily transferable to civilian occupations. The same reason, transferability of skills, is probably not a factor in the earlier separation of combat occupations although operational tempo, posting localities, and family pressures may play a greater role in the decisions of combat officers.

Finally, class standing was found to yield a significant result. Those officers graduating in the top third of their TBS class had a hazard 86 percent of those in the middle third and those in the bottom third had a hazard of 124 percent compared with the middle third. This may reflect a relationship between TBS class standing and a successful job match, or alternatively, those with lower TBS class standing may self-select out of the USMC.

Neither gender nor ethnicity was found to be significant. All else being equal, a female is no more or less likely to survive than a male and there was no ethnicity that had a hazard larger or smaller than those officers classified as white. The significance of ethnicity and gender has varied in earlier studies; however, where they are found to be significant they are rarely practically significant.

2. Non-parametric Model Results Summary

The non-parametric model indicates that optimum numbers for prior and non-prior enlisted officer accessions can be obtained using the two constraints of force structure and allocated budget. However, when the data are subdivided, the sample size becomes too small for accurate Kaplan-Meier estimates. Additionally, the subdivision of data by commissioning source does not allow all the variables in the model to be present and, as a result, the model fails or becomes questionable.

The results of the non-parametric model indicate that the optimum number of prior enlisted officer accessions is 272 (22.4 percent) and the optimum number of non-prior enlisted officer accessions is 944 (77.6 percent) for a total of 1,216 officer accessions annually. These figures differ significantly when compared to recent trends in which the number of prior enlisted officers to non-prior enlisted officers was 53.4 and 46.6 percent respectively in 1999 (49.7 to 50.3 percent over the period 1995-1999).

The large difference between the optimum and the current trend may have several consequences which will not be observed for at least another five years. Overall, the survival rates of officers are likely to increase. This has the secondary impact on increasing the number of officers available for promotion at any rank. If promotion is based only on the billets available, and not on time in rank, then there will be more officers available for promotion than required which may result in increases in time-in-rank, competitiveness for promotion, and ultimately forced separations to maintain end-strength.

The optimum number of officer accessions with respect to prior or non-prior enlisted officers differed significantly across the three identified occupational categories of combat, combat support, or combat service support. The optimum for prior and non-prior enlisted officers in combat-related occupations was 67 (18.5 percent) and 295 (81.5%) respectively. The optimum for combat support-related occupations was 200 (38.2 percent) and 323 (61.8 percent). And finally, the optimum for combat service support-related occupations was 10 (3 percent) and 324 (97 percent).

The relatively low optimal number of prior enlisted officers for combat and combat service support-related occupations reflects the high separation rates for officers in these occupations. Higher numbers of prior enlisted officers would result in an increase in officers available for promotion and too many O-4's. However, potential cost savings exist where non-prior enlisted accessions are replaced with the less expensive prior enlisted accessions and the overall number of accessions can be reduced. This would result in fewer O-1 to O-3's; however survival rates would increase.

B. RECOMMENDATIONS

1. Accession Policy Review

Based on the results of this thesis, there is evidence to suggest that the trend observed in officer accessions in the most recent years of the data may not represent the most useful allocation of given resources. Assuming full expenditure of the allocated funds for accession is desired, the current accessions of prior enlisted officers may be too high which will result in too many officers at the O-4 level. The model indicates that it is possible to reduce the accession budget and maintain the force structure by changing the numbers of prior and non-prior enlisted officers.

It is recommended that the ratio of accessions for prior and non-prior enlisted officers be further reviewed with the view to reducing prior enlisted officer accessions, particularly to combat and combat service support occupations. It should be recognized that although high retention rates are normally considered desirable they may also result in forced attrition, increased time-in-rank for promotion, and ageing of the force. Subsequently a balance should be obtained such that attrition rates are sustainable. Dramatically increasing or decreasing accessions through any of the commissioning sources is not recommended however MECEP and USNA have higher retention rates than other commissioning sources.

2. Cox Regression Methods

Many quantitative studies of USMC manpower have used logit and ordinary least squares methods for analysis of data. Although these methods may be appropriate depending on the research topic, where the topic concerns survival rates and uses censored data, Cox regression methods should be considered.

When logit models are used with censored data they often exclude valuable information arising from the duration of the 'survival', opting instead to code the information in a binary manner. Ordinary Least Squares is an entirely inappropriate method for analysis of censored data owing to its inability to deal with limited dependent variables or censored data. In contrast, the Cox regression method is specifically designed to enable analysis of censored data using the duration of survival.

C. FUTURE STUDY

1. Performance of Prior Enlisted Officers

This thesis has not considered the relative performance of prior and non-prior enlisted officers and has instead assumed their performance to be approximately equal. Performance is often best measured by the promotion of an individual and the scores obtained on performance reports. The data available for this study only allowed the observation of an individual up to the rank of O-4 where promotions are largely (although not exclusively) automatic. Beyond O-4, promotions become more competitive and it may be possible to observe performance. The data necessary to observe performance accurately would need to trace officers beyond 15 years and preferably to the rank of O-6 or higher. If data were available, such as performance report data, then a comparison of the performance of prior enlisted officers would complement the results of this thesis.

2. Recalculation of Accession Costs with Respect to Marginal Costs

As stated earlier, a major limitation for the optimization of prior and non-prior enlisted officer accessions was the inability to determine marginal costs for accessions for each of the commissioning sources. It is likely that the use of marginal costs would change the linear relationship of variables by the allocation of some secondary costs which are not captured using the average cost for each commissioning source. However, where the optimum can be obtained by the fiscal and force structure constraints, similar methodology to that used in this thesis can be considered. Further research could therefore consider accession optimization using marginal costs of officer accessions.

3. Analysis Using Additional Cohorts

The determination of the optimum number of prior and non-prior enlisted officer accessions relied heavily on the Kaplan-Meier estimates to determine the force structure constraint. The Kaplan-Meier estimates used in this thesis relied upon only a few observations of the survival rates, so as further data become available the recalculation of the survival rates would allow better Kaplan-Meier estimates and, subsequently, a more accurate force structure constraint. The use of additional cohorts or the availability of additional data for the cohorts used in this thesis would also permit a recalculation of the Cox Regression Model and confirmation of the results.

4. Difference Between Occupations

This thesis identified a difference in the survival rates and optimum number of prior and non-prior enlisted officers between each of the three broad occupation categories; combat, combat support, and combat service support. Due to the number of MOS categories, significant amounts of data would be required to conduct this same study using individual MOS as a variable (rather than the three occupation categories); however, focused research may be possible on several of the larger MOS groups. The reasons for the very large difference in survival rates between the occupations are not clear and should be subjected to further analysis. A study of the factors that impact the separation decisions of officers with respect to their MOS may also reveal the reasons for the underlying differences between the occupation categories.

APPENDIX A. TRANSITION MATRIX FOR PRIOR ENLISTED OFFICERS

Year Group

Year Group

From\To	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	1.00													
2			0.99												
3				0.99											
4					0.87										
5						0.90									
6							0.96								
7								0.96							
8									0.96						
9										0.97					
10											0.97				
11												0.96			
12													0.95		
13														0.96	
14															0.97
15															

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX B. TRANSITION MATRIX FOR NON-PRIOR ENLISTED OFFICERS

Year Group

Year Group

From\To	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	1.00													
2			1.00												
3				0.99											
4					0.93										
5						0.87									
6							0.92								
7								0.94							
8									0.93						
9										0.95					
10											0.95				
11												0.95			
12													0.94		
13														0.98	
14															0.98
15															

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Allison, Paul D. *Survival Analysis Using the SAS® System: A Practical Guide*. Cary: SAS Institute Inc., 1995.

Andersen, P. K. "Testing Goodness of Fit of Cox's Regression and Life Model." *Biometrics*, 38: 67-77.

Asch, Beth J. and Warner, John T. "The Economics of Military Manpower." *Handbook of Defense Economics*, Vol. 1 (1995): 347 – 397.

Asch, Beth J. and Warner, John T., *A Policy Analysis of Alternative Military Retirement Systems*. RAND, 1994.

Bernard, Joel P., and Mehay, Stephen L. *An Analysis of Alternate Accession Sources for Naval Officers*. Monterey, California: Naval Postgraduate School, May 2003.

Bowman, W. R., *Cost-Effectiveness of Service Academies: New Evidence from Navy Warfare Communities*. United States Naval Academy Economics Department and Office of Institutional Research Working Paper, June 1995.

Cotton, John L. and Tuttle, Jeffrey M., "Employee Turnover: A Meta-Analysis and Review with Implications for Research." *The Academy of Management Review*, Volume 11, Number 1, (January 1986): 55-70.

Cox, D. R. "Regression Models and Life Tables." *Journal of the Royal Statistical Society, Series B,* (1973): 187-220.

Department of the Navy, Headquarters United States Marine Corps, *Marine Corps Enlisted Commissioning Education Program (MECEP),* Marine Corps Order MCO1560.15L, Washington D.C., August 1994.

Department of the Navy, Headquarters United States Marine Corps, *Enlisted-to-Officer Commissioning Programs*, Marine Corps Order MCO1040.43A, Washington D.C., May 2000.

Defense Manpower Data Centre, *Military Manpower Training Report*, *FY March 2002*, Department of Defense.

Ehrenberg, Ronald and Smith, Robert., *Modern Labor Economics: Theory and Public Policy*, 8th Ed. Addison Wesley, 2003.

Ergun, Levent. "An Analysis of Officer Accession Programs and the Career Development of U.S. Marine Corps Officers." Master's Thesis, Naval Postgraduate School, Monterey, California, March 2003.

Finley, Todd R. “A Statistical Analysis of the Performance of Naval Academy Graduates at the Basic Officer Course.” Master’s Thesis, Naval Postgraduate School, Monterey, California, June 2002.

Hiatt, Catherine M. and Quester, Aline O., *Final Report: Street-to-Fleet Study. Volume II: Street-to-Fleet for Commissioned Officers.* Centre for Naval Analysis, Alexandria, Virginia, February 2001.

Morita, June G., Lee, Thomas W., Mowday Richard T. “The Regression Analog to Survival Analysis: A Selected Application to Turnover Research.” *The Academy of Management Journal*, Vol. 36, No. 6 (1993): 1430-1464.

North, James H. and Smith, Karen D., *Officer Accession Characteristics and Success at the Officer Candidate School, Commissioning and The Basic School.* Virginia: Centre for Naval Analysis, December 1993.

North, James H. and Smith, Karen D. *Officer Accession Characteristics and Promotions to Captain and Major.* Virginia: Centre for Naval Analysis, November 1993.

O’Brien, William E. “The Effect of Marine Corps Enlisted Commissioning Programs on Officer Retention.” Master’s Thesis, Naval Postgraduate School, Monterey, California, June 2002.

Parcell, Ann D. *Optimizing Officer Accession Sources*. Virginia: Center for Naval Analyses, October 2001.

Parcell, Ann D., Hodari, Apriel K., and Shuford, Robert W. *Predictors of Officer Success*. Virginia: Centre for Naval Analysis, April 2003.

Smith, Tyler, Smith, Besa, and Ryan, Margaret A.K. *Survival Analysis Using Cox Proportional Hazards Modeling for Single and Multiple Event Time Data.* San Diego: Department of Defense Centre for Deployment Health Research, Naval Health Research Centre.

Wooldridge, Jeffrey M. *Introductory Econometrics: A Modern Approach*. South Western College Publishing, 1999.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Marine Corps Representative
   Naval Postgraduate School
   Monterey, California

4. Director, Training and Education, MCCDC, Code C46
   Quantico, Virginia

5. Professor Stephen Mehay
   Graduate School of Business and Public Policy
   Naval Postgraduate School
   Monterey, California

6. Professor Katherine Kocher
   Graduate School of Business and Public Policy
   Naval Postgraduate School
   Monterey, California

7. Professor Sam Buttrey
   Operations Analysis Department
   Naval Postgraduate School
   Monterey, California

8. Library
   Australian Defence Force Academy
   Campbell, Australian Capital Territory, 2601
   AUSTRALIA

9. Major Phillip Hoglin
   Directorate of Workforce Planning - Army
   Department of Defence
   Canberra, Australian Capital Territory, 2600
   AUSTRALIA